

SHIP PRODUCTION COMMITTEE  
FACILITIES AND ENVIRONMENTAL EFFECTS  
SURFACE PREPARATION AND COATINGS  
DESIGN/PRODUCTION INTEGRATION  
HUMAN RESOURCE INNOVATION  
MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
EDUCATION AND TRAINING

August 1987  
NSRP 0281

# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

## **1987 Ship Production Symposium**

### **Paper No. 31: A Study of the Construction Planning and Manpower Schedules for Building the Multi- Purpose Mobilization Ship, PD214...**

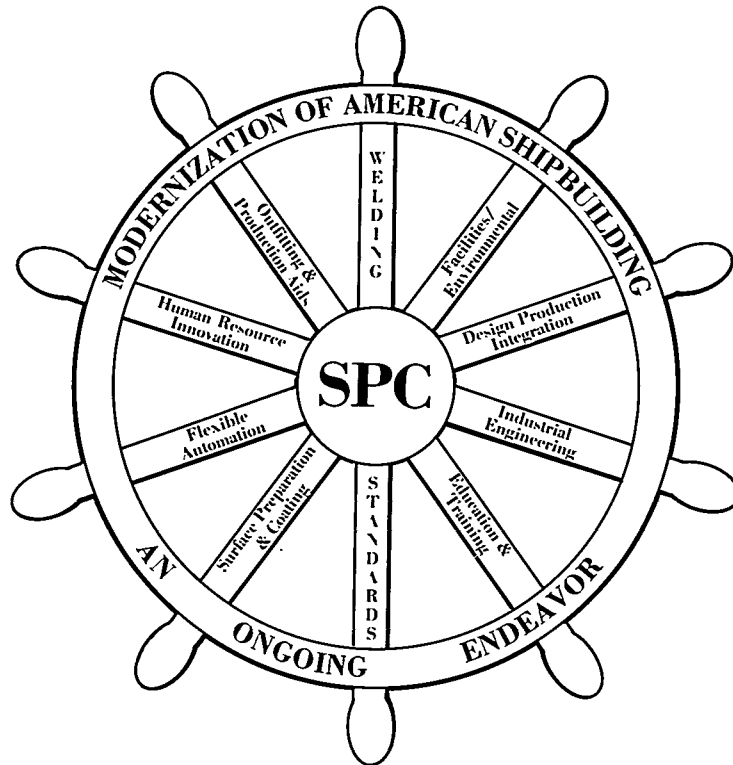
U.S. DEPARTMENT OF THE NAVY  
CARDEROCK DIVISION,  
NAVAL SURFACE WARFARE CENTER

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>AUG 1987</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>The National Shipbuilding Research Program 1987 Ship Production Symposium Paper No. 31: A Study of the Construction Planning and Manpower Schedules for Building the Multi-Purpose Mobilization Ship, PD214</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>33</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## DISCLAIMER

These reports were prepared as an account of government-sponsored work. Neither the United States, nor the United States Navy, nor any person acting on behalf of the United States Navy (A) makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this report/manual, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or (B) assumes any liabilities with respect to the use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in the report. As used in the above, "Persons acting on behalf of the United States Navy" includes any employee, contractor, or subcontractor to the contractor of the United States Navy to the extent that such employee, contractor, or subcontractor to the contractor prepares, handles, or distributes, or provides access to any information pursuant to his employment or contract or subcontract to the contractor with the United States Navy. ANY POSSIBLE IMPLIED WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR PURPOSE ARE SPECIFICALLY DISCLAIMED.

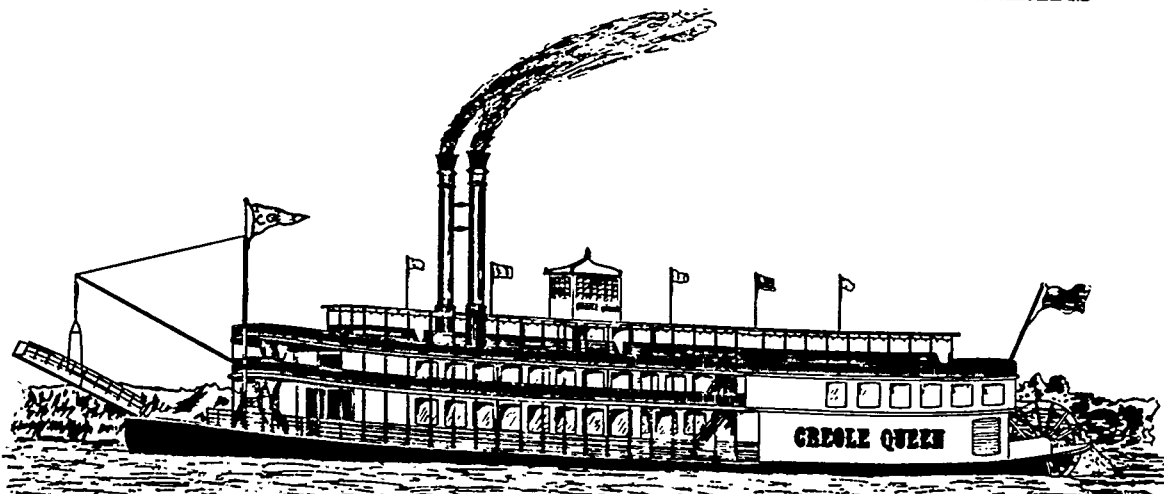
# NSRP 1987 SHIP PRODUCTION SYMPOSIUM



AUGUST 26-28, 1987  
HYATT REGENCY HOTEL  
New Orleans, Louisiana



HOSTED BY THE GULF SECTION OF THE  
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS





# A Study of the Construction Planning and Manpower Schedules for Building the Multi-Purpose Mobilization Ship, PD 214, in a Shipyard of the People's Republic of China

No. 31

Howard M. Bunch, Member, Transportation Research Institute and Department Naval Architecture and Marine Engineering

## ABSTRACT

This paper presents the results of a study for building five PD-214 ships in a shipyard of The People's Republic of China. The study was performed by the author in 1987 at the Men jiang She.mulding Institute, The People's Republic of China A comparison of shipbuilding planning and resource expenditure estimates is made for building a series of identical ships in an advanced shipyard in the United States and in The People's Republic of China.

## INTRODUCTION

The People's Republic of China (PRC) is generally regarded as a future major force among the world's shipbuilding nations. Starting about 1980 (known in China as the beginning of the "Reform"), the country placed major emphasis on a plan to upgrade its shipbuilding industry to be one of the world's leaders. Throughout the decade of the eighties, the Chinese shipbuilding industry has shown growth averaging a compounded increase of about 13.7 percent/year. [1]<sup>1</sup> Importantly, an expanding portion of its output is being placed into the export market. [2] The tentative plan, according to Hu Chuanzhi, Managing Director of China State Shipbuilding Corporation (CSSC), is to have an annual output in excess of one million deadweight tons by 1990 [3]. Approximately one-third would be for the export market.

This study is the presentation of the construction planning and manpower schedules for building five PD214 general mobilization ships at Hudong Shipyard, Shanghai. (Earlier studies developed the construction plans and manpower schedules for building five PD214 ships at a shipyard

in Japan and at a shipyard in the U.S.A. All studies used the same designs and made similar assumptions [4] [5].)

Hudong Shipyards, Shanghai, was selected as the shipyard for which the schedules and estimates would be prepared. It is one of the most advanced yards in the nation, and has been designated as a facility where major priority would be given to the implementation of advanced technology.

In January, 1987, the Chinese government announced new rules to "...promote the system of factory directors assuming full responsibility for production and management...".[6] The new system makes the director fully responsible for production and management of the enterprise, with the political organization (which exists in all Chinese enterprises) being assigned the role of advisor. Now, the enterprise director has the right to control production and to make decisions on finance. He also has management appointment responsibility, and the right to "praise" and/or "punish" the worker. Hudong Shipyard has been designated as one of the enterprises to implement the new rules on a pilot basis. This designation was further indication that the yard is considered one of the most progressive in China, and confirmed its selection.

The research was performed by the author and a team of staff and graduate students of Zhenjiang Shipbuilding Institute (located in Zhenjiang, Jiangsu Province, PRC) during 1986-87. The team received the constant advise and counsel of Hudong's managers and engineers during the effort. All analyses and projections were approved by Hudong management as being accurate representations of the yard's planning documentation.

The baseline ship for the study was the PD214 general mobilization ship [7] with the following options multi-purpose design, Jumbo size option, steam turbine (vice

<sup>1</sup>Numbers in brackets designate References at end of paper.

diesel) main propulsion plant, cargo cranes. and a slewing stern ramp. The study was prepared on the basis of practices and facilities in place in 1987, with a contract signing on January 1, 1986. Other study assumptions were

- (a) the construction contract was signed on the final day of business negotiations;
- (b) the engineering working drawings for the ship were complete and available to the shipyard at signing of the contract;
- (c) the total shipyard facility was available to construct the five ships, and no existing contracts or follow-on work would impact the PD214 schedules;
- (d) five ships of the PD214 (Jumbo) class were ordered in the contract, and all were identical;
- (e) purchase orders for equipment, materials, and supplies would be issued subsequent to receipt of the contract; and
- (f) the five ships would be consecutively constructed in the shipyard's main facility.

Figure 1 shows the inboard profile view and the main deck of the PD214 (Jumbo) ship. Table 1 is a listing of the principal characteristics of the ship. Table 2 is a list of the appropriate laws and classifications that would apply to construction of the PD214. The complete description of the ship with options is contained in the referenced Marad report. [8]

This paper is divided into four sections. First, there is a discussion of Hudong's facilities and organization. Then there is an analysis of the construction methods employed; next, a presentation is made of the time and man-hour budget for each of the production activities. Finally, general conclusions are made from the analyses,

Comparisons are made throughout the paper with the facilities and operations of Avondale Shipyards, Inc., New Orleans, Louisiana. The information and data source "for the Avondale comparison is a similar study [9] that developed the construction schedules and manpower planning to build a like series of PD214 general mobilization ships. In the Avondale case, however, the date of contract award was 1/1/83--some three years earlier than the contract date assumption used in the Hudong study. (And, the reader should be aware that Avondale's facilities and productivity factors are now considerably different than those shown.)

TABLE 1  
PRINCIPLE CHARACTERISTICS  
PD-214 -GENERAL MOBILIZATION SHIP  
JUMBO OPTION

Length Overall	719'
Length Between Perpendiculars	670'
Beam(Molded)	97'
Depth(Molded)	61'
Draft (Full Load)	30'
Draft (Scantling)	35'
Light Ship	14,500 L.T.
Crew Effects-and Stores	50 L.T.
Fuel Oil	3,000 L.T.
Cargo Oil	3,900 L.T.
Fresh Water	340 L.T.
S.W. Ballast	4,900 L.T.
Lube Oil & Diesel Oil	60
Cargo Deadweight	19,960 L.T.
Total Deadweight	23,310 L.T.
Total Displacement	37,380 L.T.
Bale Cubic Holds	1,963,900 Cu.ft
Liquid Cargo Volume	17'4.800 Cu.ft
Crew Accommodations	37
Extra Mobilization Accommodations	7
Total Accommodations	53
Horsepower (Max. Continuous Rated	22,500
Speed (Knots 100% Power)	21.1
Speed (Knots 80% Power)	20.1
Fuel Consumption @ SEA (bbl/day)	840
Fuel Consumption @ Port (bbl/day)	86
Range (In Nautical Miles)	13,800
Propeller -6 Blades	22'4"
Total Containers On Deck (TEU)	436
Total Containers Below Deck (TEU)	850
Total Containers (TEU)	1,286

## FACILITIES DESCRIPTION AND ORGANIZATION<sup>2</sup>

Hudong Shipyard is one of the three largest yards in the Shanghai area it builds a variety of ships, including coastal oil tankers, coastal passenger and cargo vessels, oceangoing vessels, oceanographic research ships, oil drilling ships, and military frigates. [10] The yard is capable of producing ships up to 70,000 DWT; additionally, it has a diesel engine production facility that builds marine engines up to 25,000 brake horsepower. Table 3 shows the yard's production output for the five-year period, 1982-86.

<sup>2</sup>All material in this section was obtained during a series of interviews with Hudong Shipyard management. The interviews occurred in Shanghai during March and April, 1987.

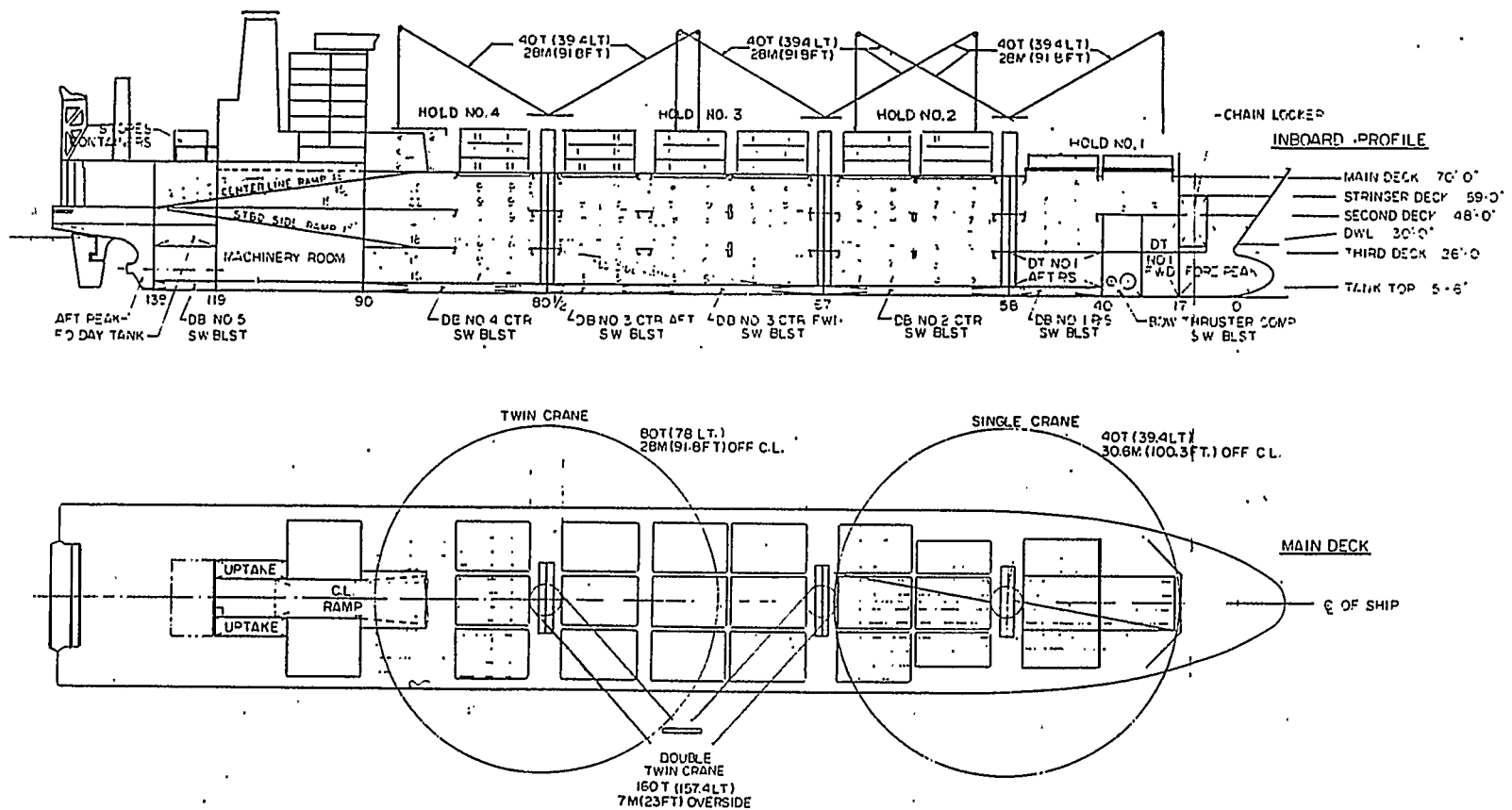


Figure 1: INBOARD PROFILE AND MAIN DECK PD214 GENERAL MOBILIZATION SHIP

---

TABLE 2  
LIST OF APPROPRIATE LAWS AND  
CLASSIFICATIONS THAT WOULD APPLY TO  
CONSTRUCTION OF THE PD214

---

- ABS Classification Rules + AIE + E + AMS
- U.S. Coast Guard, including International Rules of the Road
- USPHS Publication \*393 (Sanitation) and PB1610I9 (Ratproofing)
- SOLAS Convention 1974
- USCG Panama Canal and Suez Canal Tonnage Certificates
- Panama Canal Company Regulation
- Suez Canal Company Regulation
- IEEE #45
- Federal Communication Commission
- ABS Cargo Gear Requirements
- USDL Safety and Health Regulations for Longshoring

---

Source: References 4, 5.

---

The total employment for the yard was 12,000 persons on March 1, 1987, distributed as follows

Shipbuilding Division (Workers)	3,785	(31.4%)
Engine Division (Workers)	1,898	(15.8%)
Management	1,507	(12.6%)
Engineers	1,014	( 8.5%)
Service	1,100	( 9.2%)
All Others	22.5%	
 Total	 12,000	 (100.0%)

Organization for the entire shipyard is shown in Figure 2. Besides the Shipbuilding Division, other line units are the Engine Division, the Material Supply Department Civil Engineering Department,

and the Chief Engineer's Office. Administrative and staff groups include the Chief Economist, Accounting Department, and the Personnel Department.

The Engine Division designs, fabricates, and markets the low- and medium-speed engines, and associated auxiliaries. The unit also has large forging, casting, and heat treating shops.

The Material Supply Department is responsible for acquisition and transportation of all materials for the yard.

The Civil Engineering Department does all of the civil engineering projects for the yard, including employee housing. The group maintains all of the yard's facilities and all stationary equipment and tools. In addition, the department is responsible for the construction of all industrial projects that are fabricated and assembled at the yard. (An example would be steel bridges that the yard builds.)

The Chief Engineer is responsible for quality control, metrology, and for all other technology management within the yard, including physical and chemical analyses. The unit directs the CAD/CAM developments and application program.

On the staff side, the Economics Officer is responsible for long term planning, labor balance coordination, and contract administration. The Chief Accountant deals with all financial matters. The Personnel Division is responsible for training, education, personnel administration, and operation of the numerous support groups (like the hospital, visitor hostel, and children's nurseries).

---

TABLE 3  
PRODUCTION OUTPUT FOR HUDONG SHIPYARD  
FOR A FIVE-YEAR PERIOD, 1982-1986

---

Year	Ship Production* (DW Tonnes)	Engine Production (Horse-Power)
1982	62,000	63,000
1983	91,000	95,000
1984	104,400	129,000
1985	117,500	133,600
1986	102,300	136,900

\*--Excludes military production, estimated at less than two Jianghu-class frigates/year.

Source: Hudong Shipyards

---

The Shipbuilding Division is the principal division in the yard. This division has approximately one-half of the yard's total workforce in its organization. There are four departments and six production shops/factories in the division.

The Shipbuilding Design Department designs the ships, including advanced concepts. It prepares production working documents, as well as material for regulatory approval. The Production Management

Department handles the production management for the entire yard; It has responsibility for preparing production plans and coordinating of the shop production. The Shipbuilding Planning Department performs the work load balancing it prepares the production instruction and coordinates the milestone schedules. And the Safety Department is responsible for safety in the entire shipyard

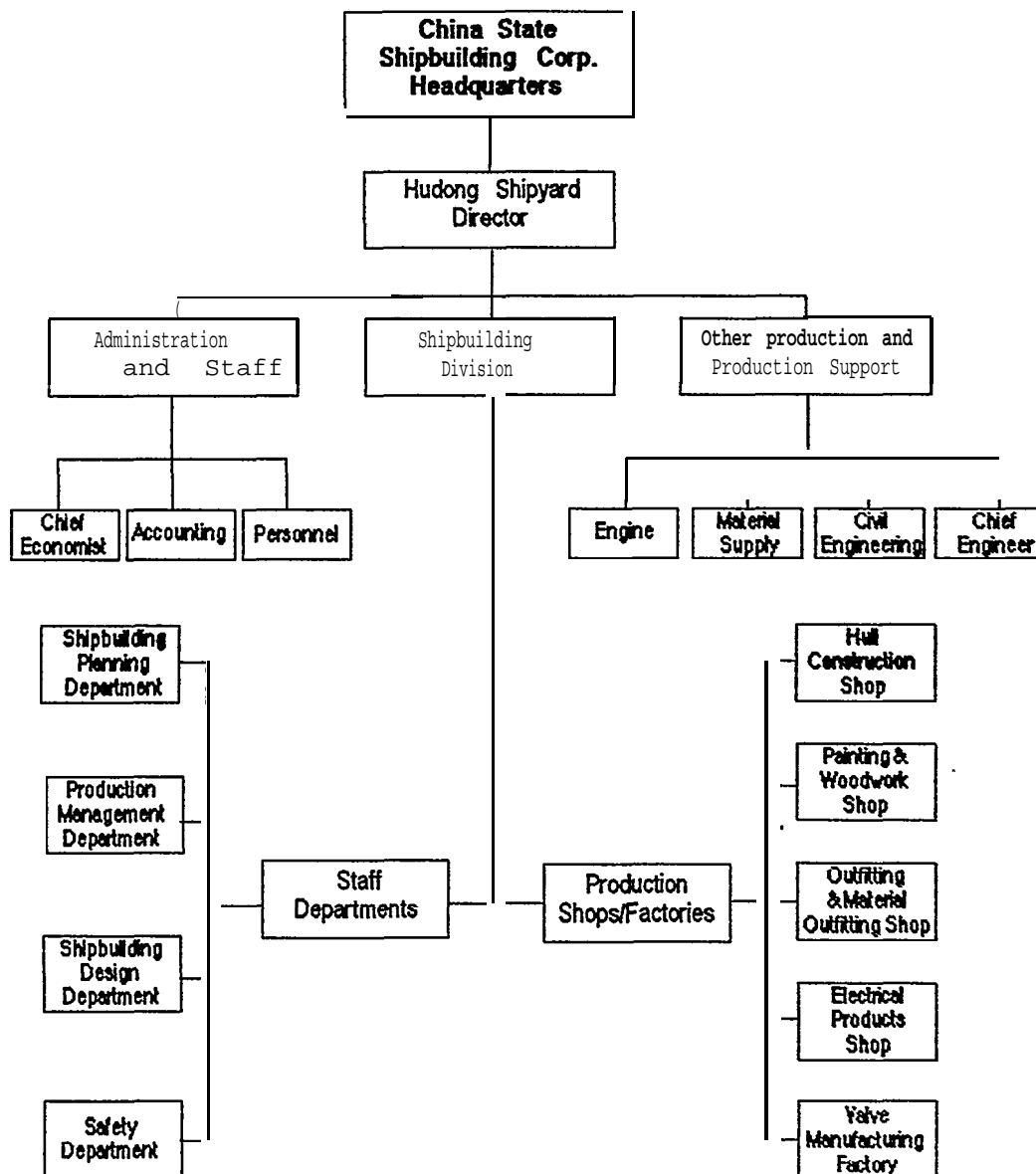


FIGURE 2: HUDONG ORGANIZATIONAL CHART

The Hull Construction Shop is one of the main shops for the division. It is responsible for all of the steel production for both ship and industrial products, and associated lofting.

The Machinery and Electrical Workshop is responsible for installation of the main engines, the navigational equipment, the electrical equipment, and sea trials. This shop is also responsible for processing of pipe, and its installation aboard the ship. It is considered one of the strongest shops in the yard.

The Painting and Woodworking Shop is responsible for all painting and coating operations and all woodworking jobs, including the manufacturing and installation of any wooden furniture.

The Outfitting Material Fabrication Shop makes foundations, doors, boilers, small hatch covers, and aluminium doors/windows, and runs the galvanizing and oxide finishing operations. The shop does not perform any of the installation activities.

The Electrical Products Factory fabricates switchboards, cabinets, steel furniture and ship models. Its products are also sold outside the shipyard.

The Valve Factory manufactures all valves used on the ship. The casings are manufactured by the Casting Shop--a unit in the yard's Engine Division.

There is a labor union organization in Hudong; however, it is structured differently than in an American or Japanese yard. First, there is no focus on craft orientation by the union, and there are no work rules requiring that work be performed only by people with a recognized Journeyman skill. As a result, workers can be, and are, cross-crafted in their assignments.

There is only one labor union, and 90 percent of the workers participate. Some of the workers are elected to represent all of the workers they are called "Workers' Representatives". The labor union leaders are elected from these representatives. At Hudong there are 1,000 Workers' Representatives, and about 40 labor union leaders.

About twice each year the shipyard director is obliged to make a formal report to the Workers' Representatives. After this meeting the representatives will caucus in a series of small, special focus sessions to develop comments on the director's report. Their comments will contain suggestions and recommendations for future

direction of the yard, as well as suggested action for management.

The Workers' Representatives will also make decisions concerning how to allocate and spend the workers' portions of the company's profits. The worker's share is about 15-20 percent of the company's net profits. The management is bound to follow the Workers' Representatives directions on the profits allocated to the workers. There is no absolute requirement that management follow the suggestions/recommendations on any other topic.

The labor union leaders have the function of following up on the suggestions/recommendations of the Workers' Representatives. They make detailed reports to the representatives at the meetings as to what happened relative to each recommendation during the preceding period.

At Hudong shipyard, and at all Chinese enterprises, the union is under the leadership of the Communist Party. The Communist Party organization has a structure in the shipyard that replicates the production/management organization. At Hudong the party (or political) structure is comprised of about 200 persons. About 80 percent (160) are assigned full-time to the structure. The head is the Chief Political Officer. This person is always a member of the Communist Party and is elected to this position by a vote of the Communist Party members in the shipyard. At Hudong, this man is a university graduate who has been at the yard for all of his working career. Prior to becoming Chief Political Officer, he was head of the shipyard director's administrative office.

Figure 3 shows the layout for the ship-building portion of the shipyard as of January 1, 1987. (It should be noted that there is presently a 36,000 square meter assembly shed under construction. The facility will be completed in 1988, and will considerably enhance the production capability of the yard. The new facility is not shown in Figure 3.)

The total yard embraces 913,000 square meters (212 acres) of land, most of which is devoted to the ship production activities.

Table 4 shows the size of the ship production facilities, and makes a comparison with Avondale shipyards--a typical American yard, [11] As seen, the ship production area at Hudong is considerably less than that found at Avondale. The difference is especially evident in the space devoted to fabrication and to erection.

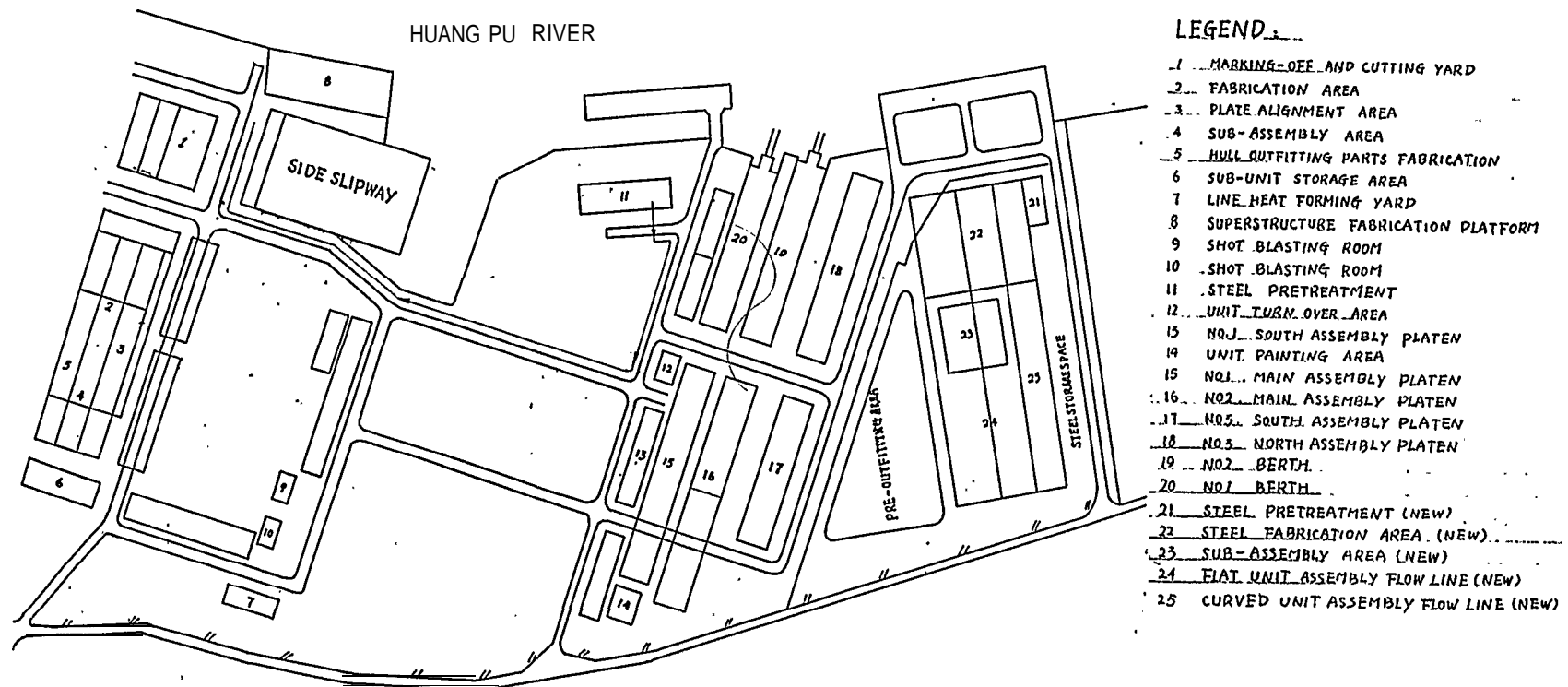


FIGURE 3: LAYOUT OF HUDONG SHIPYARD SHIP PRODUCTION FACILITIES

TABLE 4  
SIZE OF PRODUCTION FACILITIES  
AT HUDONG AND AVONDALE SHIPYARDS  
(IN SQUARE FEET)

Production Category/	SHIPYARD		RATIO	
	Hudong'		Avondale <sup>Ω</sup>	
	Current(1/1/87)	Future(1988)	Current(t.11m)	
	(A)	(B)	(c)	A/c B/C
Fabrication	138,460	310,680	318,800	.43 .97
Sub-Assembly	99,030	314,330	112,700	.88 2.79
Assembly	335,190	335,190	441,150	.76 .76
Erection	203,480	203,480	421,800	.48 .48
Total	776,160	1,163,680	1,294,450	.60 .90
Approximate Processing Capacity (s. tons stl/Yr.)	33,075*	88,200*	50,400@	
Ratio ft <sup>2</sup> /tons/vear	23.5	13.2	25.7	

\* Based on steel pre-treatment flowline capacity of 30K tonnes/year. After expansion, the steel capacity will be 88,200 tons of steel/year. Erection facilities will then be the limiting facility.

@ Based on average erection rate of 4200 tons/month [12]

Source: Hudong Shipyard Interview

<sup>Ω</sup> Source: Avondale Study

Currently, Hudong only has one slipway capable of building the PD214 ship.

Hudong's production facilities will be considerably enhanced when its new assembly shed is completed in 1988. At that time the total ship production space will nearly equal Avondale's, and the sub-assembly area will be nearly twice that of Avondale's.

Table 4 also relates the facility space with the stated steel production capacity for the two yards. (The indicated capacity is for the individual production unit that has the smallest tonnage output. For Hudong, this is the steel pre-treatment facility with an indicated capacity of 33,075 short tons/year (30,000 tonnes/year). At Avondale, expected erection rate is stated as 4200 short tons of steel/month which is the same as the capacities of the assembly lanes.) As seen, Hudong's utilization ratio **currently is 23.5ft<sup>2</sup>/ton**, Avondale's is **25.7ft<sup>2</sup>/ton**. **Completion of the new assembly shed will significantly change Hudong's utilization ratio because the steel throughput capacity will increase to about 80,000 tons/year. The facility area/throughput ratio for Hudong will then become 13.2ft<sup>2</sup>/ton.**

Both Hudong and Avondale have approximately the same profile of open-versus covered-production facilities. The fabrication facilities are under cover at both

yard; sub-assembly is partially covered at both yards; and assembly and erection are in the open at both yards.

Table 5 summarizes the machinery and crane capacities utilized by Hudong in its ship fabrication and assembly operations. Comparison of these specifications with those found at Avondale in like operations reveals many similarities. The gas cutting machines are of approximately the same capacity, each yard has the same number of numerical cutting and optical cutting machines; and each has about the same profile of forming equipment, even though there are marked differences in the capacities (Avondale's equipment is generally larger).

There are major differences in the shipyards' operational capabilities. The most significant differences are found in the cutting operations, welding operations, pipe shop operations, CAD/CAM operations and painting operations.

Of especial significance is the fact that Hudong does not have any plasma-arc cutting equipment. As a result its thermal cutting is confined to mild steels of less than 60,000 psi yield. Aluminum and high-alloy materials are cut mechanically.

Automatic and semi-automatic welding operations are more extensive at Avondale than at Hudong. At Hudong, approxi-

mately 55 percent of all welding is done manually; the percentage is considerably less at Avondale.

Avondale's pipe shop is nearly fully automated. Hudong's pipe fabrication is completely manual, and is also segmented into three separate operating locations (thus reducing potential benefits from economics of scale),

Avondale has utilized CAD/CAM throughout its operations for several years, being one of the earliest American shipyards to emplace CADAM graphics software. Hudong, on the other hand, is only now beginning to utilize the more advanced systems of CAD/CAM software. Further, Hudong's planning and management control systems are still not fully emplaced on a computer data base.

Finally, Avondale has automated many of its paint shop operations by the use of robots in the application of coatings in hazardous and difficult situations. While both

Hudong and Avondale have large paint sheds for painting complete blocks, Avondale's environmental controls are more complete and finely tuned than those found at Hudong.

The only major difference in the lift capacities for the two yards is found at the erection site. Hudong can lift 400 tonnes (by combining the four 100-tonne cranes). Avondale's capacity at the erection site is limited to a 200-ton lift. On some unique circumstances, a 400-ton lift can be accomplished by combining the two gantry

Because there is significant ground movement of the blocks at Hudong, the capacity of the flatbed carriers is a limiting factor. The yard has one 150-tonne flatbed carrier, and for that reason no block can exceed 150 tonnes unless it is built at a location where the gantry cranes from the slipways have direct access.

---

---

TABLE 5

DESCRIPTION OF FABRICATION MACHINERY  
AT HUDONG SHIPYARD

1. Gas Cutting Machines: 5, with all but one being numerical control. Layout is 24m x 4m x 100mm.
2. Plasma Arc Cutting Machines: None.
3. with largest having a 500-ton capacity.
4. Bending Machines: 3, largest is 13m x 43mm radius.
5. Plate Straightener One 5-roll, and one 7-roll machine.
6. Shears: None.
7. Plate-Edge Plans: 2, largest is .12m x 80mm.
8. Frame Machines: 2, largest is 400-ton capacity, with thickness of 400mm.
9. One-Side Welding Fixture 2, largest is 12m x 24mm.
10. Submerged Arc Welding Machines: Several all portable, except for one-side welding fixtures described above.
11. Crane Lifting Capacity:

<u>Location</u>	<u>Number</u>	<u>Largest Unit</u>
Cutting Area	4	15 tons
Fabrication	2	5 tons
Sub-Assembly		
(including panel line)	10	15 tons
Inside Assembly Workshop	4	30 tons
Outside Assembly and Erection Areas		
Horizontal Berth	8	40 tons
Inclined Berth	16	100 tons
Quays	2	40 tons

Source: Hudong Shipyards

---

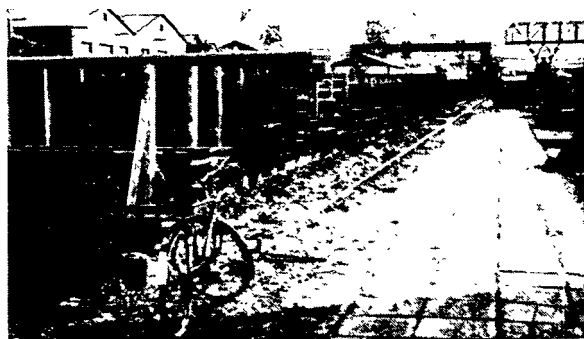
---

Figure 4 displays some scenes of the Hudong ship production facilities. The reader's attention is especially directed to the photographs of the pipe and structures storage and the fabricated parts and sub-assembly storage. In China, the national planning system permits the ordering of material only two times per year. As a result, the purchasing department does much anticipatory ordering and stockpiling of material to prevent outages. The result is seen in the large amount of pipe and structural material found in the storage lot (Figure 4a).

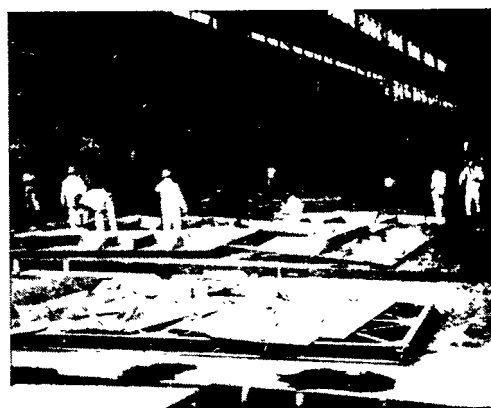
The photographs of the fabricated parts and sub-assembly storage areas (Figures 4c and 4d) indicate the extent to which the yard cuts and fabricates parts for future use. The large numbers of identical parts

reflect the extent to which the yard builds "standard" ships, and the confidence that the identical parts will eventually be called for by the assembly operations.

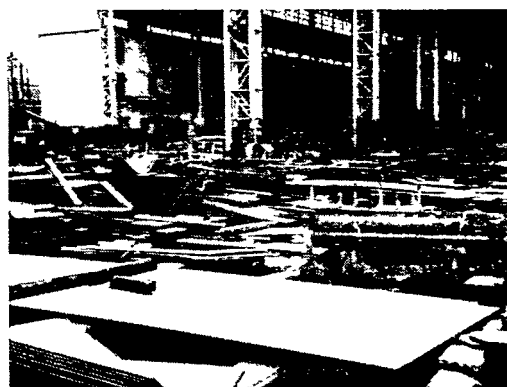
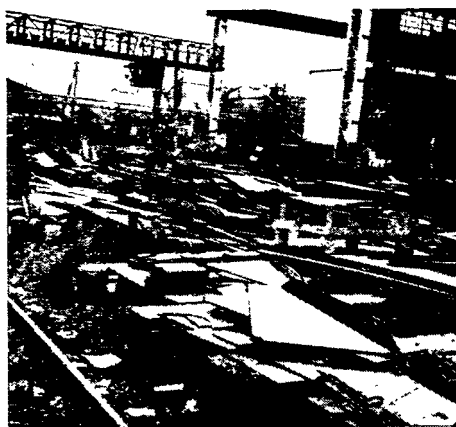
A final observation concerning Hudong's facilities relates to the use of permanent jigs in the assembly of curved blocks. Until recently all of the Jigs at Hudong were of the permanent rigid style, indicating that the yard constructed the Jigs fully expecting to reuse them several times. This fact indicates that the yard's management felt their work would be almost exclusively directed toward ships of a standard design. The yard has only recently acquired and installed pin Jigs, indicating its feeling that future work might contain one-of-a-kind ship construction projects.



4.a Pipe and Structures Storage

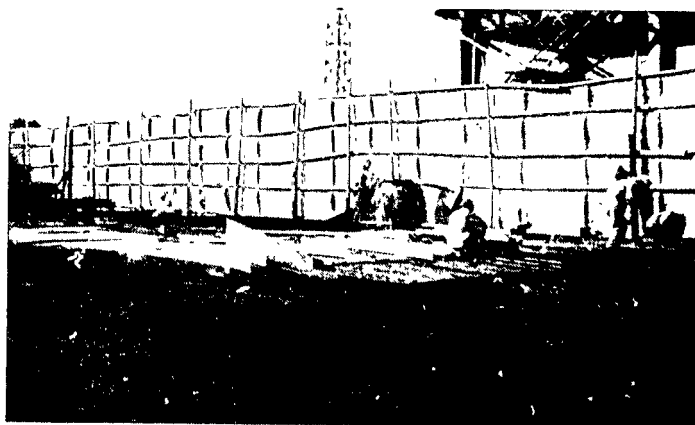


mbl

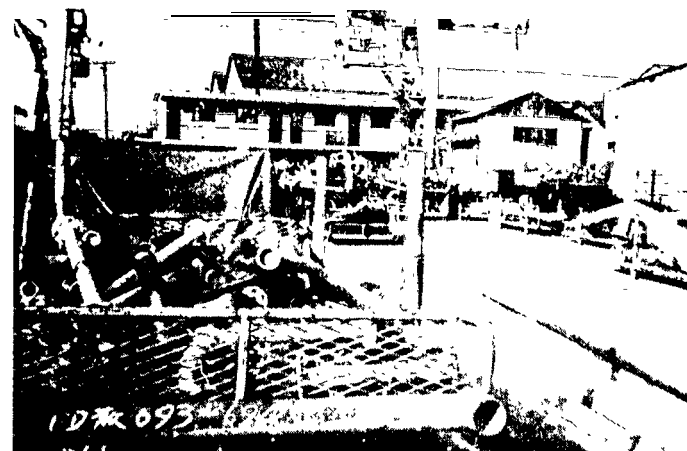


4,c and 4.d Fabricated Parts and Sub-Assembly Storage

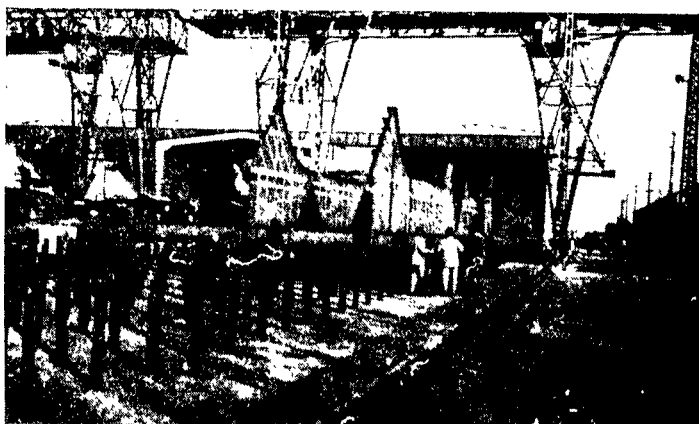
FIGURE 4: VIEWS OF HUDONG SHIPYARD



4.e Small Block Assembly



4.f Pallet Storage for Piping

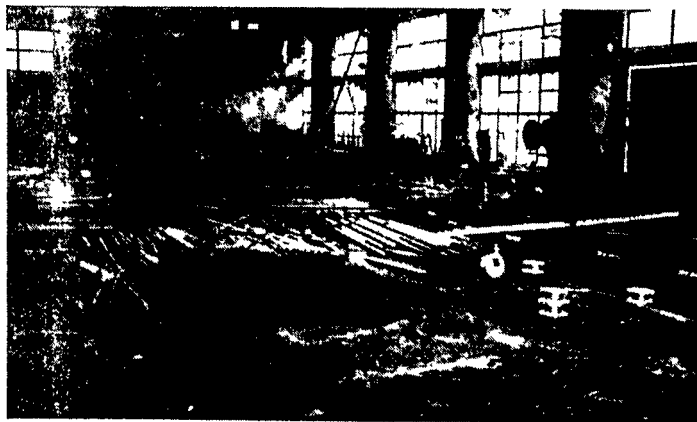


4.g Flat Block Assembly



4.h Superstructure Assembly

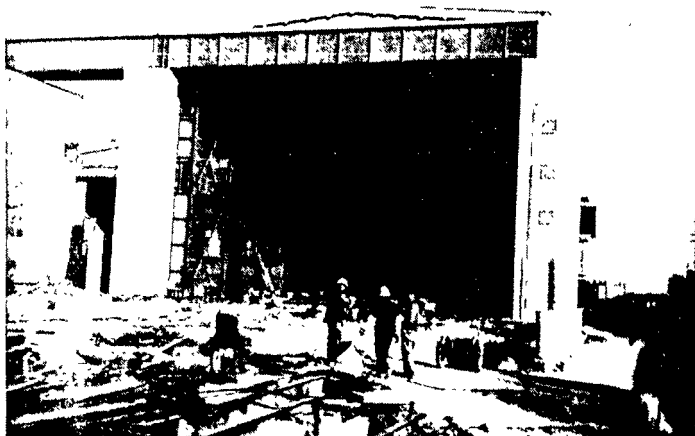
Figure 4 (continued): Views of Hudong Shipyard



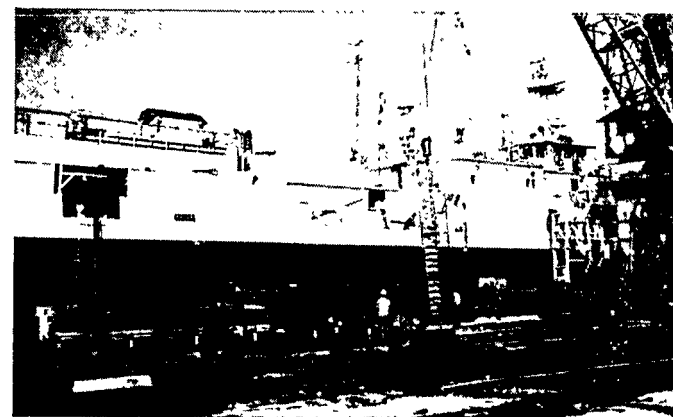
4.1i Small Pipe Fabrication Facility



4.j Portion of Superstructure and Curved Unit Assembly Platens



4.,k Block Painting Facility



4.1 Horizontal Building Berth Facility

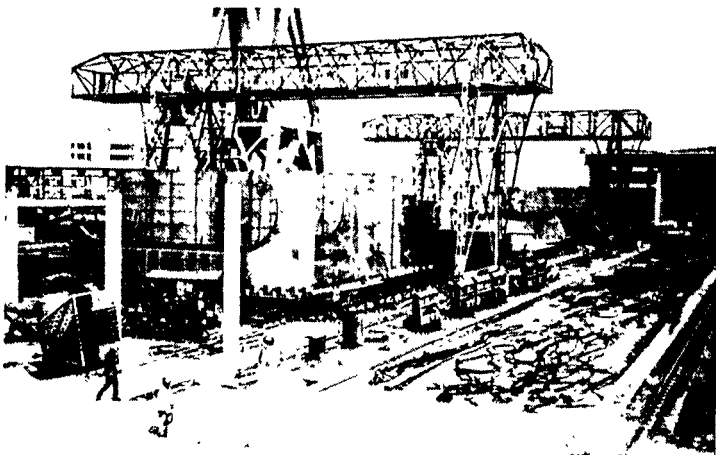
Figure 4 (continued) Views of Hudong Shipyard



4.m Fabricated and Sub Assembly Parts Storage



4.n Fixed Jig used for Block Assembly of Navy Ship

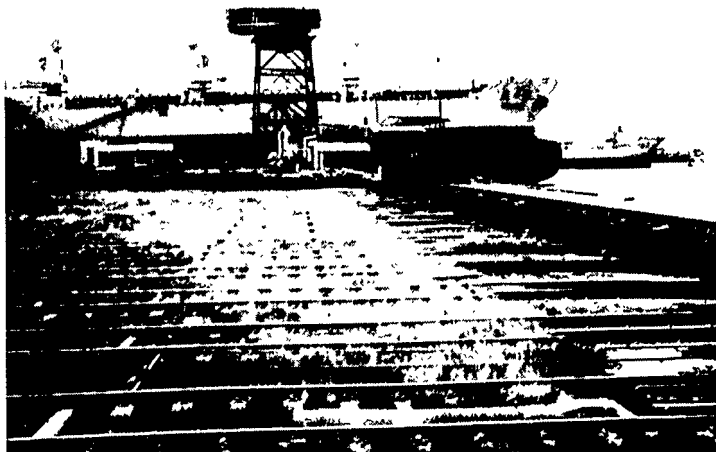


4.o Flat Block Final Assembly



4.p Block with Partial Outfitting

Figure 4 (continued): Views of Hudong Shipyard



4.q Horizontal Berth Launch Area



4.r Industrial Product Assembly



4.s Storage of Fittings Manufactured in Yard



4.t Sub Assembly Area

Figure 4 (continued): Views of Hudong Shipyard

## CONSTRUCTION METHODS

Figure 5 is an isometric presentation of Hudong's block definition for the PD214. In making the divisions, Hudong's planners followed these principles

- no block to exceed 180 tonnes, except for the superstructure final lift
- attempt to control the weight of most blocks to less than 100 tonnes;
- attempt to pre-outfit blocks before erection;
- avoid breaking blocks at the major stress zones (e.g., the areas of the big hatches in the decks);
- recognize the standard steel plate sizes in making the block breaks (lengths of 6, 8, 10, and 12 meters, widths of 1.5, 1.8, and 2.0 meters);
- make breaks at major ship's structure points, especially in the Dow and stern, and
- make breaks so that the most effective construction technology can be utilized.

For comparison, Avondale's block definitions for the same ship are shown in Figure 6. There are areas of major difference in the break points for the two yards, Hudong, for example, divides its double bottoms so that the centerline units in the mid-ship section extend to the outboard longitudinal bulkheads (35' 6" off centerline). The entire bilge radius is included in a side-shell block. Avondale, on the other hand, divides the double bottom into three sections the centerline unit that includes the pipe tunnels (14' 6" off center-line), and the port/starboard outboard units that includes part of the bilge radius. Figure 7 shows the block-breaks in the mid-body area in the two yards. (Avondale completes many of its double-bottom blocks before erection starts. Their unit break points permit easy storage of the completed blocks by simply stacking them. On the other hand, Hudong would have only four blocks completed when erection starts, and storage would not be a factor in the break point decisions.)

Another difference is at the break points for the side-shell blocks. Hudong makes its break at the 3rd deck or below; Avondale divides its units at the 2nd deck.

A third major difference occurs in the superstructure. Here, Hudong divides each deck of the structure into a port and starboard unit the two-unit sequence is caused by the fact that erection occurs after launch, and transporters must move the

units from the assembly area to quay-side. At Avondale, space and lift limitations don't exist and the superstructure is erected as a single unit.

Although Hudong has not implemented group technology through a rationalized product work breakdown structure, the yard does have in place a process system that incorporates many of the features of product work breakdown. As Table 6 shows, hull structure blocks are divided into six categories

- a. Cargo area double bottoms, bilges, decks, and ramps (standard flat blocks);
- b. Three-dimensional side shells, decks with side shells (special flat blocks);
- c. Engine room double bottoms (curved and/or flat blocks of heavy weight);
- d. Bow and stern curved sections (curved special blocks);
- e. Superstructure;
- f. Hatches, transverse and longitudinal bulkheads and beams (other blocks).

Hudong divided the ship into 194 production blocks, each with an average weight of 56.9 short tons (51.6 tonnes), as shown in Table 6. There was a wide dispersion in the block sizes, with the standard deviation calculated at 27.7 short tons, or 48.7 percent of the average weight. For comparison, Avondale's block count is 210, with an average weight of 52.7 short tons. Standard deviation was 20.5 short tons, or 38.9 percent of the average weight. The data shows clearly that Hudong does not maintain the same consistency of block size as Avondale this fact can also be visually verified by close examination of Figures 5 and 6, the isometric views of the block divisions for the two shipyards.

Table 6 shows, for each category, the following information: block count and its percentage of the total count, the weight range of blocks, the total steel weight for the category and its percentage of the grand total, the average weight of the blocks, the dispersion of these weights (expressed as standard deviation), and distance of movement of the material as it is being processed. The same information is also shown for Avondale's production system for comparison.

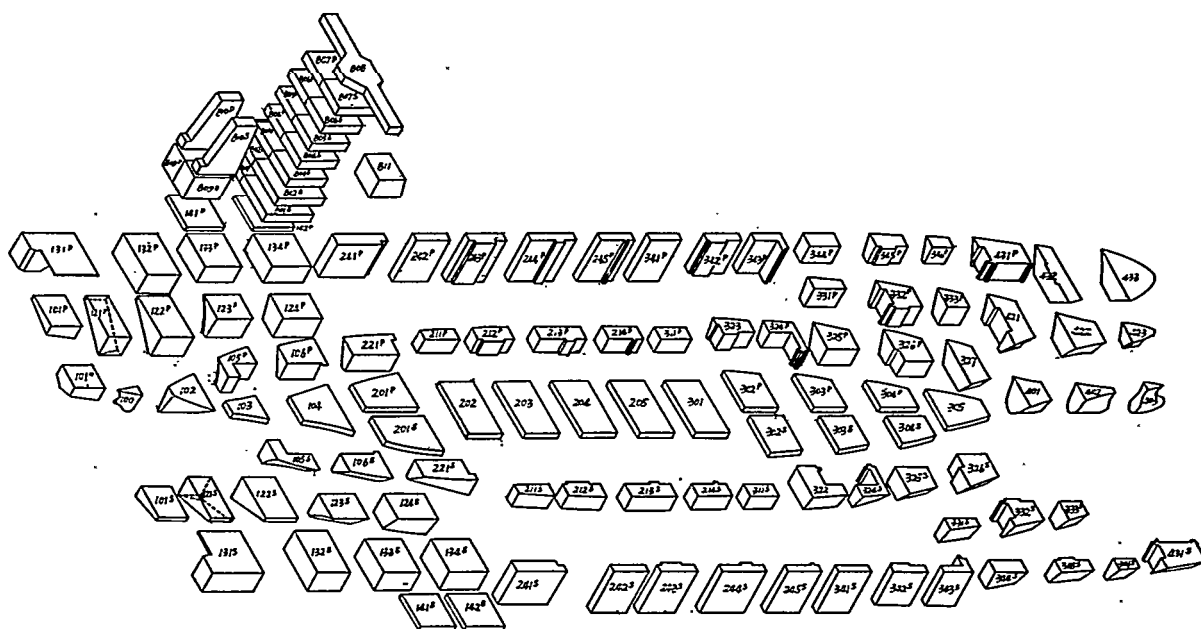


FIGURE 5: ISOMETRIC VIEW OF HUDONG'S BLOCK DIVISIONS

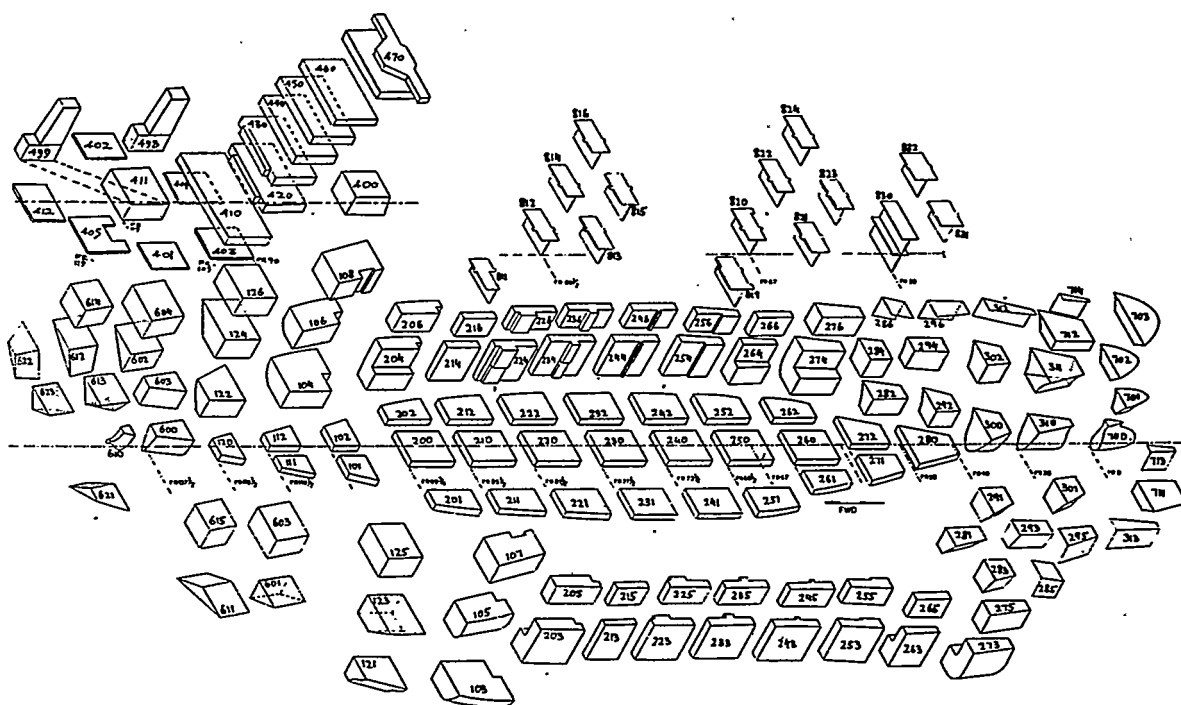


FIGURE 6: ISOMETRIC VIEW OF AVONDALE'S BLOCK DIVISIONS

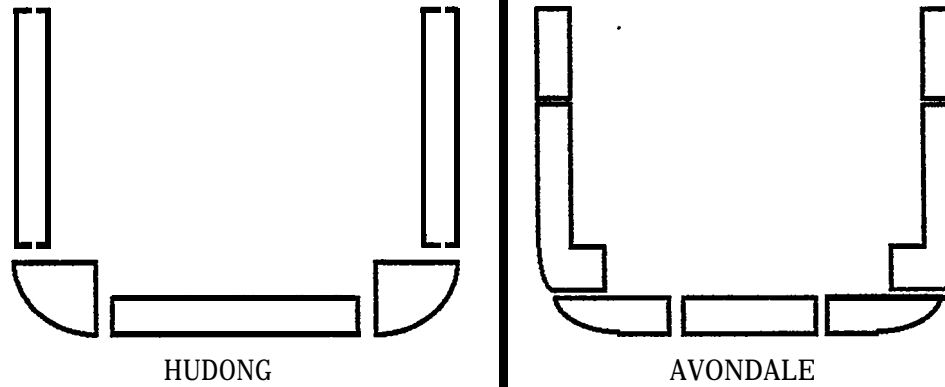


Figure 7: Schematic of Block Divisions at Midship Section for Hudong and Avondale Shipyards

TABLE 6  
BLOCK PRODUCTION CATEGORIES FOR HUDONG AND AVONDALE SHIPYARDS

HUDONG SHIPYARD								
BlockCategory	count		Range	weights (Shorttons)			Process Path	
	#	%		sum	% of Total	Avg.	Sigma	Distance(ft)
A.-Flat(cargo area double bottoms bilge, decks, and ramps.)	51	26.3	4.9--143.5	3,498	31.7	68.6	39.4	7,870
B.-FlatSpecial(3-dimenziom&iide-shell, deckd with side-shells.)	63	32.5	21.9--155.7	5,023	45.5	79.8	35.3	7,870
C.-Curved (Engineroom double bottoms.)	2	1.0	50.7--142.9	194	1.8	96.8	46.2	7,550
D.-CurvedSpecial (Bow and stern)	15	7.7	13.2--138.9	1,191	10.8	79.4	31.1	8,350
E.-Superstructure	20	10.3	25.1--31.1	541	4.9	27.0	3.8	6,250
F.-Other(hatch, transverse and horizontal beams)	43	22.2	2.8-41.7	588	5.3	13.7	7.3	7,400-8,050
TOTALS	194	100.0	2.8--155.7	11,035	100.0	56.9	27.2	7,800

A VONDALESHIPYARD								
BlockCategory	count		Range	Weights (short tons)			Process Path	
	#	%		sum	% of Total	Avg.	Sigma	Distance(ft)
1.-Flat Pannel Units(mid part, double bottoms, side-shells, long blkheads)	97	46.2	9.7-123.9	6,814	61.6	70.2	29.0	7,050
2.-Curved Shell Units (Aft&Fore PartUnits, side shell.)	31	14.8	19.3-100.6	1,630	14.7	52.6	24.6	2,900
3.-superstructure	19	9.0	23.1-71.2	807	7.3	42.5	14.6	2,850
4.-Fore Peak and Aft Peak Units (large & very heavy 3D curved)	13	6.2	13.1-97.2	778	7.0	59.5	34.9	2,900
5.-EogineRoomInner Bottoms(large and Heavy, intricate, flat units)	6	2.9	31.0-97.2	292	2.6	48.7	22.2	4,600
6.-Special Units (skegs, rodders, bulbous shapes, stern castings)	44	21.0	8.6--130.6	749	6.8	17.0	18.8	3,050
TOTALS	210	100.0	13.1--140.0	11,070	100.0	52.7	20.5	5,500

Importantly, Avondale has rationalized its system to incorporate the features of group technology. This rationalization has included the requirement of expanding engineering activities to meet the increased planning needs associated with group technology and zone outfitting.

The data presented in Table 6 reveals the wide dispersion of block weights within every Hudong production category. The difference between the largest block and the smallest block is great in one instance (category #1) the ratio is 29:1. For the entire ship the weight difference is a ratio of 55:1. Avondale's weight difference for its blocks is significantly less for the entire ship the ratio is 11:1 (140 tons versus 13.1 tons). And, the greater dispersion in block weights at Hudong is further confirmed by the greater standard deviation in the unit weights, as discussed earlier.

Finally, Table 6 indicates that an average ton of steel being processed for the PD214 at Hudong will travel a distance of nearly 7900 feet. (By contrast the average travel distance for a ton of steel at Avondale would be about 5500 feet.) It is noted, however, that when the new assembly shed at Hudong is completed (scheduled for mid-1988), the travel distance for a ton of steel will be significantly reduced.

The high priority that Hudong places on the time that a ship is on the slideway is indicated in Table 7. This table is a comparison of the time (in weeks) that Hudong and Avondale processed components for each of the ship's areas as a function of the production activity. For the erection activity, Hudong needed only 21 weeks; Avondale took 32 weeks or about 50 percent longer.

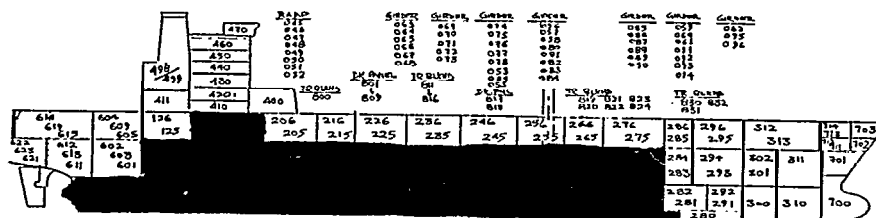
Further examination of the erection activity indicates that as the erection continues, Hudong increasingly concentrates its attention on getting the ship launched. Note that those areas of the ship that are early in the erection sequence (engine room and holds) take longer times at Hudong than at Avondale. The reverse is true for those areas that occur late in the erection process (bow, foreholds, and stern); here, the period of involvement is significantly shorter at Hudong. (In fact this phenomena exists for all of the production activities; the engine room and holds area material consistently being processed longer at Hudong than at Avondale, and the reverse is true for the foreholds, bow, and stern material. Hudong executives indicated in a personal interview at Hudong Shipyards on May 16, 1987 that this occurs because of the system of work load leveling that is employed. Hudong's system is to allow more time for the early units, thus giving the production shop additional leeway in adjusting its daily work load.)

Hudong's fabrication space is limited (as seen in Table 4, shown earlier); this is reflected in the fact that the time allowed for fabrication is greater. As Table 7 indicates, the fabrication of material at Hudong is 1.1 times that needed at Avondale. Hudong overcomes its space limitation by starting the fabrication process earlier and stockpiling material until it's needed. (The stockpiles are shown in the photographs in Figure 4.)

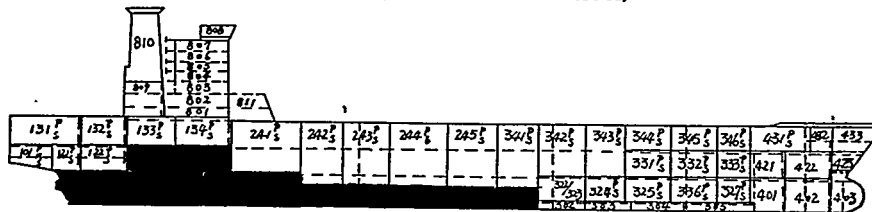
Figure 8 compares the erection status of the PD214 ship for the two shipyards at the quartile points from keel to launch: one-fourth, midway, and three-fourths. One-fourth of the way from keel to launch (five weeks after keel at Hudong, and nine weeks after keel at Avondale), depicted in Figure 8a, both shipyards have laid well over half of the double bottoms, and the

**TABLE 7**  
COMPARISON OF PRODUCTION ACTIVITY BY SHIP'S SECTION

SHIP'S AREA	Fabrication			Assembly			Erection		
	HSY		Ratio	HSY		Ratio	HSY		Ratio
	(1)	(2)	(1)/(2)	(1)	(2)	(1)/(2)	(1)	(2)	(1)/(2)
Engine Room	27	15	1.8	23	18	1.3	15	12	1.3
Holds	32	18	1.8	29	17	1.7	21	11	1.9
Fore Holds	17	21	.8	16	24	.7	6	16	.4
Stern	14	1.8	.8	23	22	1.1	14	17	.8
Bow	21	18	1.2	17	20	.9	2	15	.1
Entire Ship	32	2.8	1.1	29	30		21	32	.7

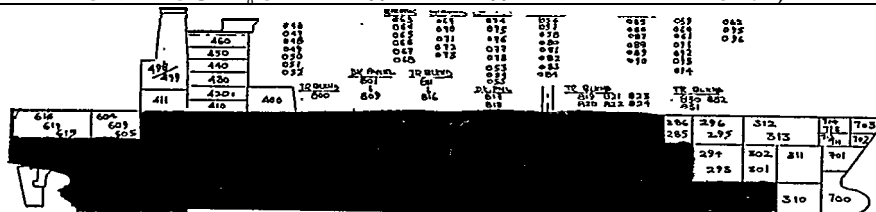


Avondale (9 Weeks After Keel)

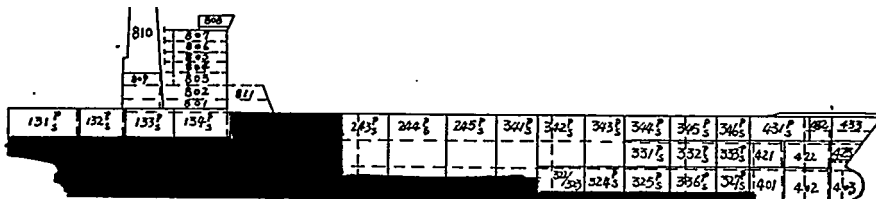


Hudong (5 Weeks After Keel)

FIGURE 8A: COMPARISON OF ERECTION STATUS HUDONG AND AVONDALE SHIPYARDS  
(ONE-FOURTH OF THE WAY BETWEEN KEEL AND LAUNCH)

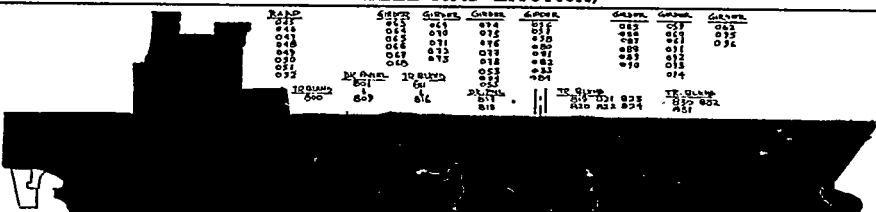


Avondale (17 Weeks After Keel)

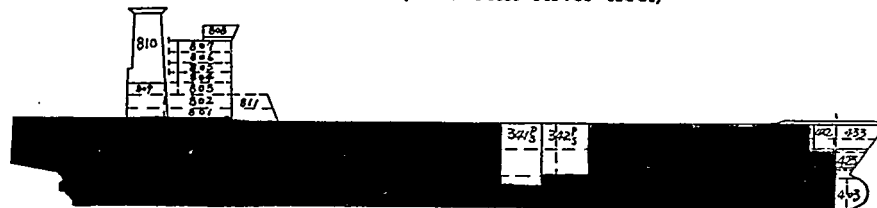


Hudong (9 Weeks After Keel)

FIGURE 8B COMPARISON OF ERECTION STATUS HUDONG AND AVONDALE SHIPYARDS  
(HALF WAY BETWEEN KEEL AND LAUNCH)



Avondale (27 Weeks After Keel)



Hudong (15 Weeks After Keel)

FIGURE 8C COMPARISON OF ERECTION STATUS HUDONG AND AVONDALE SHIPYARDS  
(THREE-FOURTHS OF THE WAY BETWEEN KEEL AND LAUNCH)

stern tube casting is in place. Avondale, however, has progressed further in its erection of side-shell units, with the major blocks in place up to the second deck. While it's not evident in the figure, both yards started their erection process at the same point the forward engine room bulkhead. And, each yard erected units both fore and aft of this point in approximately the same sequence.

At the mid-point of the erection period (shown in Figure 8b) Hudong would have finished laying all of the double bottoms, and begun to put the side-shell units in place. In the engine room area, all of the units to the second deck would be in place, and a limited number of blocks to the main-deck height would have been erected. At the same point in time, Avondale would have erected all of the side-shell blocks in the parallel mid-body area.

At the three-quarters point (Figure 8c) Hudong would have most of the ship's structure in place except for the final blocks at the bow and at the "close-up" section in the parallel mid-body. The superstructure is landed after launch. Avondale would have completed its entire erection process at this point, including the superstructure. Because Avondale has ample erection locations, its policy is to leave the ship on the erection way for an extended period while it continues outfitting work. In the case of the PD214, Avondale's schedule indicates the ship stays at the erection site for approximately nine weeks after the final block has been put in place.

#### SUBCONTRACTING

The general policy of Hudong is not to subcontract any of the production activities. On rare occasions specific portions of the engineering work will be subcontracted to another division of China State Shipbuilding Corporation, such as CSSC'S Shipbuilding Research Institute. These organizations are utilized when a technical question arises that cannot be adequately dealt with by the shipyard's own staff. Seldom, if ever, is work subcontracted because of facility overload.

It has traditionally been the policy in Communist China that each enterprise is assigned a mission, and then it is to develop itself both vertically and horizontally to accomplish that mission. Until recently there was no economic penalty imposed for such an expansion. As a result, a typical Chinese shipyard has production facilities enabling it to build, from basic raw materials, most of the equipment found on a

ship, Hudong, for example, builds its own engines, makes its own valves and fittings, and makes all of the castings and forgings that are required. Likewise, all of the support services necessary to design and build a ship are contained within the shipyard organization. The result has been a shipbuilding enterprise that typically will operate without recourse to outside sources of supply.

#### MATERIAL PURCHASING

As mentioned above, Chinese shipyards will fabricate internally as much of the equipment as possible. As a result, a greater portion of their requisitions will be for "raw materials". The remaining materials will be divided into two categories (1) those materials (or equipment) that can be purchased from domestic sources within China, and (2) those materials that must be purchased abroad.

Materials acquired within the Chinese domestic system, either raw materials or finished goods, are ordered at specified times each year. The typical order months for shipyards are February and August; at those times the purchasing agents indicate to the central organization their material needs 6-12 months into the future. These requests are then forwarded to the specified supplier, or to a supplier of the central organization's choice if it is deemed necessary to make the supplier change.

If for some reason it is necessary to acquire the material from abroad, the shipyard must first secure approval from the central organization. This process takes approximately three months; only after the approval is given will the purchasing agent be in a position to place the purchase order with the overseas supplier. Approval of the central organization is only given if one of the following conditions exist: (1) the equipment is specifically requested by the owner; (2) the material of acceptable quality is not available from a Chinese source or (3) the material is not available from a Chinese source within the time period required.

#### CONSTRUCTION SCHEDULES

Figure 9 shows the milestones for the first ship and the purchase schedule for the principal items. The figure reflects the fact that almost one-half of the items (12 out of 25) will be manufactured by the yard. (By contrast, Avondale would only

manufacture two items in-house: the funnel and tanks.)

It should also be noted that all of the principal items are purchased within the second month of the contract, in keeping with the specified purchase "window" of the central government.

Table 8 compares the lead time requirements for those items that are not purchased in the yard. The Hudong time period included an additional three months in each case to allow for the necessary approvals from the central organization.

In only one instance—the electric generator—is the Hudong lead time period greater than that at Avondale. The quicker overall delivery is reflected in the faster delivery time for the ships, as is shown in Figure 10. This figure compares Hudong's building milestones with those of Avondale. The building period for Hudong's first ship is 104 weeks after contract by contrast Avondale's building period for the first ship is 140 **weeks** after contract. A second milestone chart was prepared for Avondale

(also Shown in Figure 8) that revises the production schedule based on critical material being delivered on a schedule comparable to that found in a Japanese shipyard. In this instance, Avondale's schedule for the first ship is reduced to 117 weeks, nearly the same as that of Hudong.

TABLE 8  
LEAD TIME REQUIREMENTS FOR  
SELECTED MATERIAL, FOR THE PD214

Item	Lead Time Requirement (months)	
	Hudong	Avondale
Steel Plates	6	8
Auxiliary Machinery	12	12
Main Boiler	14	14
Bridge Console	10	15
Electric Generator	10	15
Main Turbine	14	14
Propeller	6	15
ProDeller Shaft	6	6
Steering Gear	12	12

Source: Hudong Shipyard and Avondale Shipyard

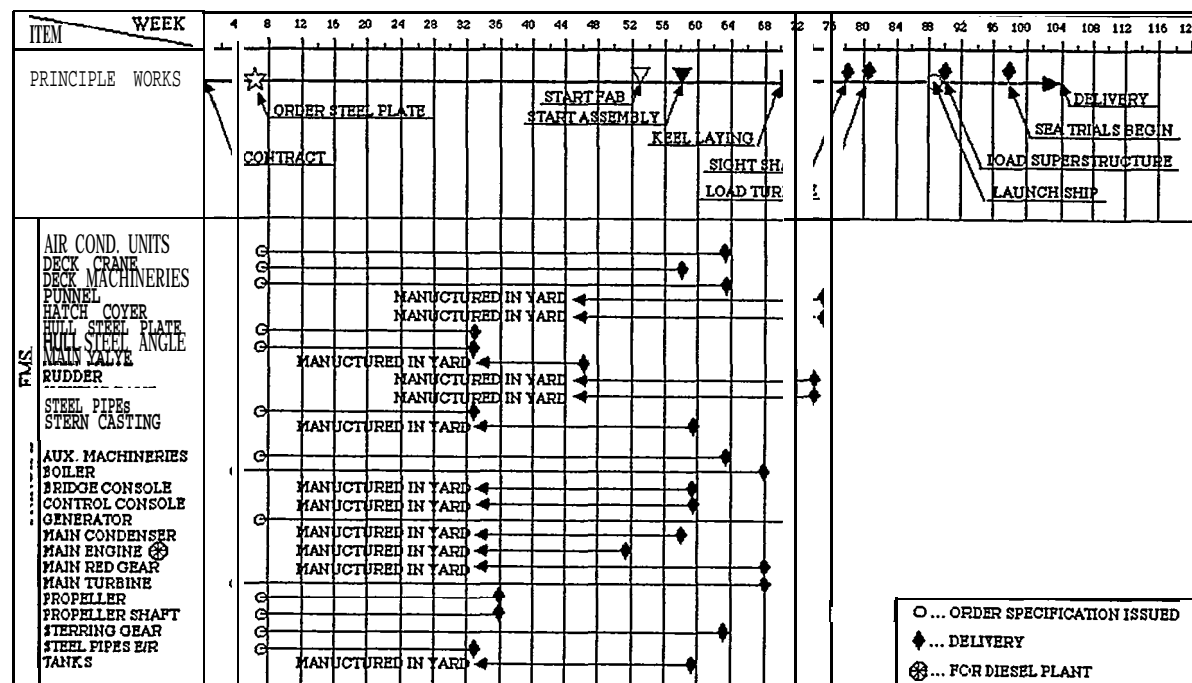


FIGURE 9: GENERAL CONSTRUCTION AND PURCHASE SCHEDULE FOR FIRST SHIP

The schedule for building all five ships is shown in Figure 11. Even though Hudong's delivery schedule is considerably less than Avondale's on the first ship, the difference nearly disappears over the five-ship series. The difference attenuation is caused by the fact that Hudong can only erect one ship at a time, whereas Avondale can have several under erection simultaneously. Hudong's fifth ship is delivered at 179 weeks after contract; Avondale's is turned over to the owner 189 weeks after contract. (It should be noted, however, that Avondale's final delivery would be 169 weeks after contract if the company were given the option of purchasing critical lead time equipment outside the United States.)

Figure 11 reflects the fact that there is a reduction in the production time for each ship as it is being processed. At Hudong this reduction is one week, from 51 **weeks** for the first ship to 50 weeks for the fifth

ship. The reduction is consistent with the experience curve benefits that are discussed later in this paper.

The effect upon changes in erection man hour rates by having only one launch way is shown in Figure 12. This illustration is a three-week-moving-average plot of the weekly erection tonnages for the five ships. The sharp valleys and fast recoveries are evident as each ship is launched and the keel for a new ship is laid. Hudong's average erection rate is 573 short tons per week over a 97 week period. As the chart visually reflects, there is wide variation in this rate the standard deviation is 241 short tons per week, or 42 percent of the average. Avondale's is only slightly better its weekly erection rate is also plotted in Figure 12 for comparison. The average is 717 tons per week, with a standard deviation of 274 tons, or 38 percent of the average.

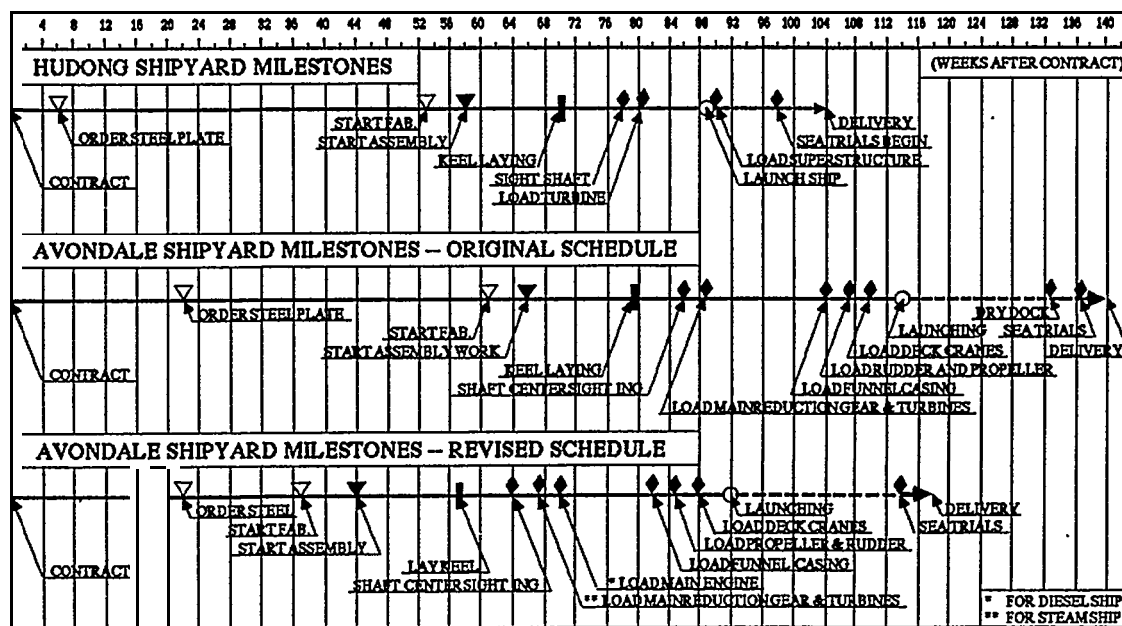


FIGURE 10: COMPARISON OF MILESTONES FOR BUILDING FIRST PD214 SHIP  
HUDONG SHIPYARD VERSUS AVONDALE SHIPYARD

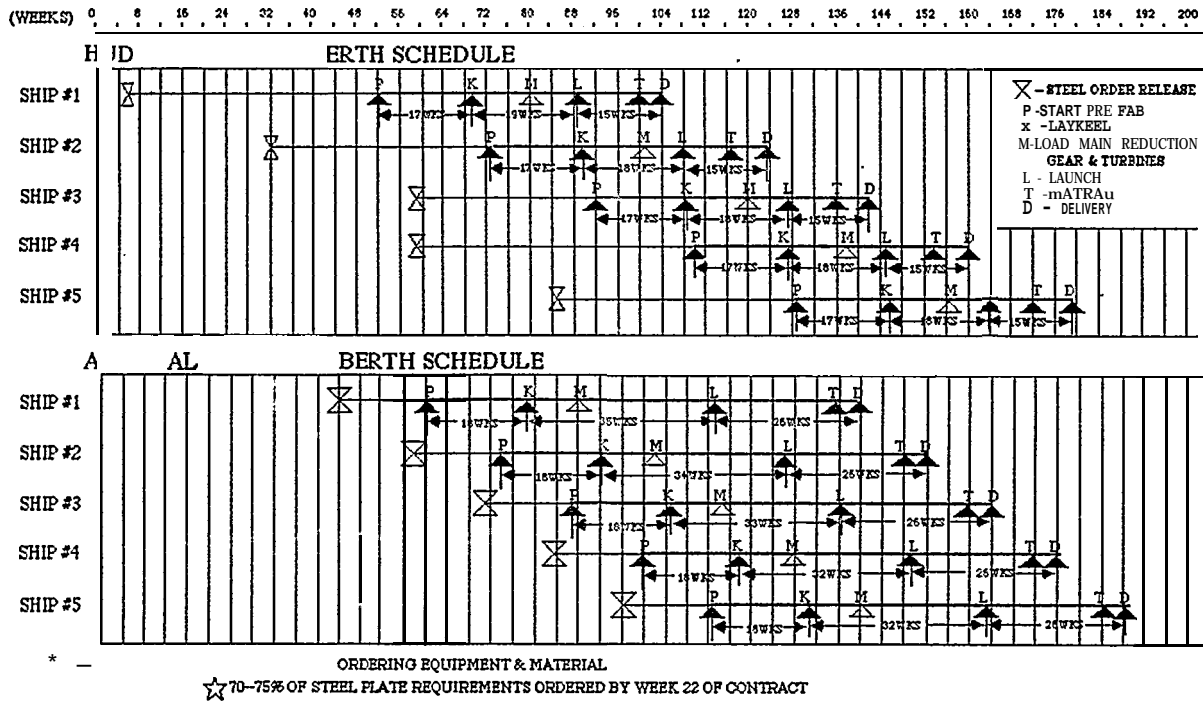


FIGURE 11: BUILDING BERTH SCHEDULE FOR FIVE PD214 SHIPS

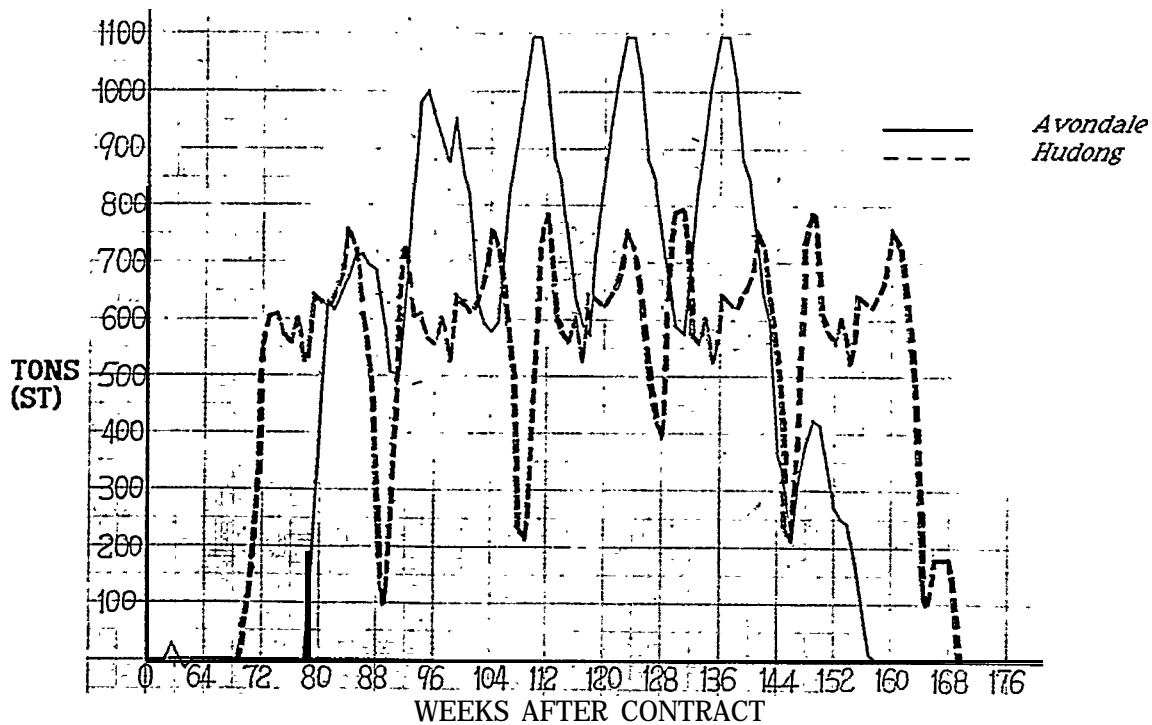


FIGURE 12: ERECTION TONNAGE SCHEDULE FOR BUILDING FIVE PD214 SHIPS  
(THREE WEEK MOVING AVERAGE)

**DIRECT MANHOURS REQUIRED TO BUILD FIVE PD 214 (JUMBO) STEAM TURBINE SHIPS  
HUDONG SHIPYARD AND AVONDALE\* SHIPYARD (000M/H)**

ACTIVITIES	SHIP NUMBER											
	1 st		2 nd		3 rd		4 th		5 th		5-ship Average	
	HSY	ASI*	HSY	ASI*	HSY	ASI*	HSY	ASI*	HSY	ASI*	HSY	ASI*
Mold Loft & Prefabrication	141	54	122	52	122	51	121	51	121	50	125	52
Hull Sub-Assembly & Assembly	491	256	478	247	471	242	462	239	457	238	472	244
Hull Erection	347	205	339	198	327	193	324	191	322	190	331	196
Fitting & Outfitting	204	143	196	139	190	136	189	135	189	134	194	137
Piping	170	125	162	115	157	110	156	108	155	106	160	113
Machine (including Sheet Metal)	261	113	247	110	245	108	243	108	241	107	248	109
Electrical	119	60	112	56	111	54	109	53	108	52	112	55
Painting (including maintenance)	212	136	208	131	202	129	201	128	197	127	204	130
Testing & Trials	30	32	28	31	27	29	27	28	27	28	28	30
All Other (including Cranes & Services)	44	165	44	159	43	156	42	155	41	154	43	158
Subtotal	2020	1289	1931	1238	1895	1209	1875	1195	1859	1188	1916	1224
Planning & Production Control Engineering	58	134	41	13	38	13	35	12	32	12	41	37
Engineering	248	412	25	41	22	39	20	37	17	35	66	113
Subtotal	306	546	66	54	60	52	55	49	49	46	107	150
Grand Total**	2326	1835	1997	1292	1955	1261	1930	1244	1908	1234	2023	1374

\* Based on a contract awarded 1/1/83. The reader should be aware that there has been significant change in Avondale's productivity since that date.

\*\*Numbers may not add correctly because of rounding.

#### MANPOWER REQUIREMENTS

In spite of the faster construction time, Hudong requires significantly more direct manhours to build the PD214 than does Avondale. The direct manhour estimates for both yards for each of the five ships are shown in Table 9. For all of the production activities Hudong requires an average of 1,916 thousand man hours for each ship, which is about 156 percent greater than Avondale's requirements for each of the five ships.

The Chinese yard offsets part of this disadvantage however, when the planning and engineering manhours are factored into the estimates. On the basis of the total direct manhours, which includes both production and engineering, Hudong is about 1.27 times greater than Avondale on the first ship (2,326 thousand manhours versus 1,835 thousand manhours), and about 1.47 times greater for the five ship average. As seen, Avondale improves on its greater investment in engineering manhours for the first ship as the series progresses. (It should be noted, also, that Avondale's estimates were developed at a time when the yard was in the throes of implementing group technology and zone outfitting technology. As a result of this implementation, engineering investment for the PD214 increased 150 thousand manhours. [13] Prior to implementation of group technology concepts Avondale's engineering investment would have been approximately that shown for Hudong.)

Relative to Table 9, it must be remembered that Avondale's estimate was based on production procedures in place as of January 1, 1983—nearly three years before Hudong's assumed contract date. During that three-year period, Avondale has probably continued to improve its productivity making the actual difference in productivity for the two yards greater than that shown in Table 9.

Table 10 rearranges the Table 9 data into summary form by major production area. The production estimates for producing the ships with a diesel engine power system (instead of the steam turbine) are also shown. As would be expected, there is a significant reduction in the manhours estimate when the diesel engine is specified—about 95 thousand manhours per ship in the case of Hudong's estimate, and approximately 65 thousand manhours per ship for Avondale. There is no change in the relationship of the estimates between the yards; Hudong requires about 1.47 times as many manhours in either case.

As would be expected, the savings in manhours by use of the diesel engine are reflected in specific areas—outfitting, painting and insulation, and engineering. The major savings occurred in outfitting where 91 thousand manhours/per ship is accounted for at Hudong, and 51 thousand manhours/per ship occurs at Avondale.

TABLE 10  
COMPARISON OF MANHOUR REQUIREMENTS FOR MAJOR PRODUCTION & ENGINEERING ACTIVITIES FOR A  
SERIES OF FIVE PD 214 SHIPS (000 M/H)

STEAM TURBINE POWER PLANT

Production Category	FIRST SHIP			5 SHIP AVERAGE			FIFTH SHIP		
	HSY	ASI	Ratio HSY/ASI	HSY	ASI	Ratio HSY/ASI	HSY	ASI	Ratio HSY/ASI
Hull Production Activities, including Mold Loft	980	515	1.90	928	492	1.89	900	478	1.88
Outfitting Activities	754	441	1.71	714	414	1.72	693	399	1.74
Painting & Insulation Activities	212	136	1.56	204	130	1.57	197	127	1.55
Testing & Trials Activities	30	32	0.94	28	30	0.93	27	28	0.96
All Other Activities	44	165	0.27	43	158	0.27	41	154	0.27
Total Production Activities*	2020	1289	1.57	1916	1224	1.57	1859	1188	1.56
Engineering & Planning Activities	306	546	0.56	107	150	0.71	49	46	1.07
Total Production & Engineering	2326	1835	1.27	2023	1374	1.47	1908	1234	1.55

\* Number may not add correctly because of rounding

DIESEL ENGINE POWER PLANT

Production Category	FIRST SHIP			5 SHIP AVERAGE			FIFTH SHIP		
	HSY	ASI	Ratio HSY/ASI	HSY	ASI	Ratio HSY/ASI	HSY	ASI	Ratio HSY/ASI
Hull Production Activities, including Mold Loft	980	515	1.90	928	492	1.89	900	479	1.88
Outfitting	658	387	1.70	623	363	1.72	606	350	1.73
Painting & Insulation Activities	212	128	1.66	204	122	1.67	197	119	1.66
Testing & Trials Activities	30	32	0.94	28	30	0.93	27	28	0.96
All Other Activities	44	165	0.27	43	158	0.27	41	154	0.27
Total Production Activities*	1925	1225	1.57	1827	1165	1.57	1771	1130	1.57
Engineering & Planning Activities	284	532	0.53	101	146	0.69	48	46	1.04
Total Production & Engineering	2209	1757	1.26	1928	1310	1.47	1819	1176	1.55

\* Number may not add correctly because of rounding

The effects of learning on productivity improvement are shown Table 11. The production activities show approximately the same rate-of-change for the two shipyards over the five ship series, with the fifth ship requiring only 90-93 percent of the manhours estimated on the first ship. The major improvement occurs in the engineering and planning activities where the estimated manpower requirements for the fifth ship is only 16 percent of the first at Hudong, and only eight percent of the first at Avondale.

On a total manhour basis, Avondale's reductions are greater than Hudong's. The American yard needs only 67 percent of the manhours for the fifth ship as for the first, whereas Hudong's reduction is only to 82 percent of the first.

There is a marked difference in the "S" curves for the two shipyards. Figure 13 displays the estimates of the cumulative expenditures of manhours, as a percentage of the total manhours. As seen, Avondale starts quicker, increases more slowly, and terminates at 100 percent later (196 weeks). Hudong has expended 50 percent of its

budget manpower at about 109 weeks, about 60 percent of the way to completion. Avondale's 50 percent point is at 118 weeks, about 60 percent of the distance to final delivery of the fifth ship.

TABLE 11  
EFFECTS OF EXPERIENCE ON PRODUCTIVITY  
IMPROVEMENT

Activities/Ship of Series	(% of 1st ship Man hours)				
	2nd ship	3rd ship	4th ship	5th ship	5 Ship Avg.
<b>Hull Production</b>					
Hudong	96	94	93	92	95
Avondale	97	94	93	93	96
<b>Outfitting</b>					
Hudong	95	93	92	92	95
Avondale	95	93	92	90	94
<b>Painting &amp; Insulating</b>					
Hudong	98	95	95	93	96
Avondale	96	95	94	93	96
<b>Engineering &amp; planning</b>					
Hudong	22	20	18	16	35
Avondale	10	10	9	8	27
<b>Total Manhours</b>					
Hudong	86	84	83	82	87
Avondale	70	69	68	67	75

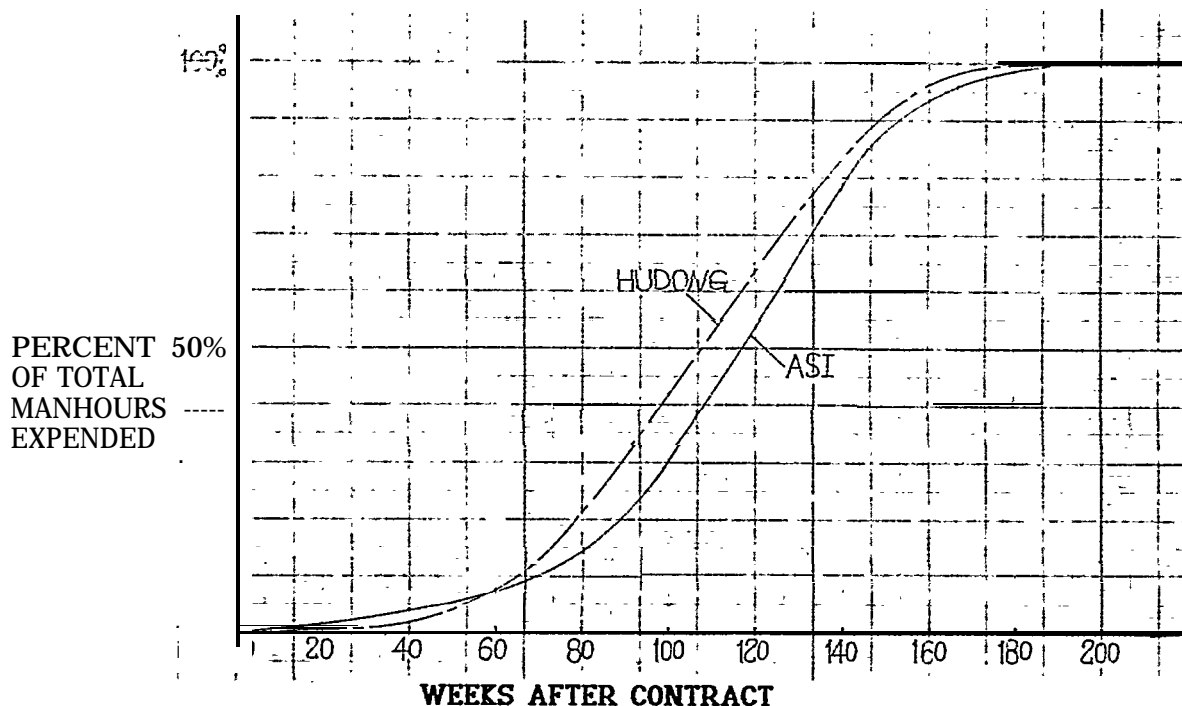


FIGURE 13: CUMULATIVE EXPENDITURE OF MANHOURS

Figures 14 and 15 show the manhour expenditure estimates on the basis of 20-week periods through the contract. Figure 14 presents the estimates for Hudong, and Figure 15 makes the same presentation for Avondale. Both tables show that the early manhour expenditure is for engineering, as would be expected. The early "production" hours shown are for production planning (which for these illustrations has been considered a production function).

Hudong's peak expenditure is during the 101-120 week period, when about 2.2 million manhours are budgeted. Avondale's peak spending period is during the 121-140 week time frame, when slightly over 1.7 million manhours are budgeted.

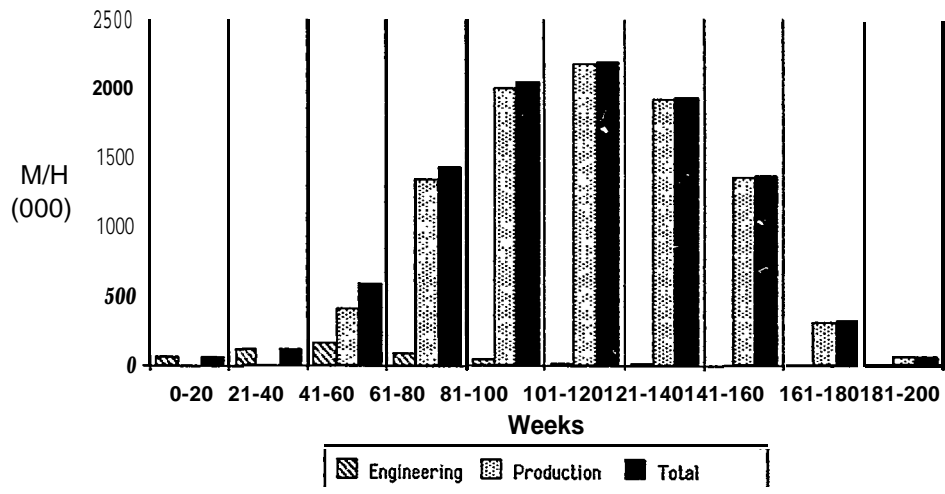
#### CONCLUSIONS

Hudong's production facilities are generally adequate for its assigned mission, i.e., building merchant ships up to approximately 70,000DWT, and navy surface ships up to about 5,000DWT. When comparing these facilities with a typical American shipyard (Avondale), one also finds the two yards approximately the same in most areas. Where differences do occur, they generally have significant impact on limiting

Hudong's ability to expand or to improve on its mission. The major deficiencies are (1) lack of plasma-arc cutting equipment; (2) lack of automatic welding equipment; (3) lack of state-of-the-art CAD/CAM hardware and software (this deficiency is currently being overcome with the installation of an IBM 4310 computer); (4) limited launch-way capacity and antiquated erection area; and (5) limited space for fabrication processes (this problem is only being partially overcome with the construction of the new assembly shed currently being built).

Hudong's organizational structure is more complex than that typically found in an American shipyard, in that it has a much more extensive basic design capability and associated equipment manufacturing capability. In fact, most of the ships built at Hudong have been designed by technical staff within the yard, and much of the outfitting equipment and machinery is built at the yard. The yard's managers are well-trained (most have university technical degrees), and are experienced (all have been in the yard most of their professional careers).

The relationship between "management" and "labor" is totally different than that found in the United States. There is only one labor union; it is controlled by the



RE

M

MA

ONG SHIPY

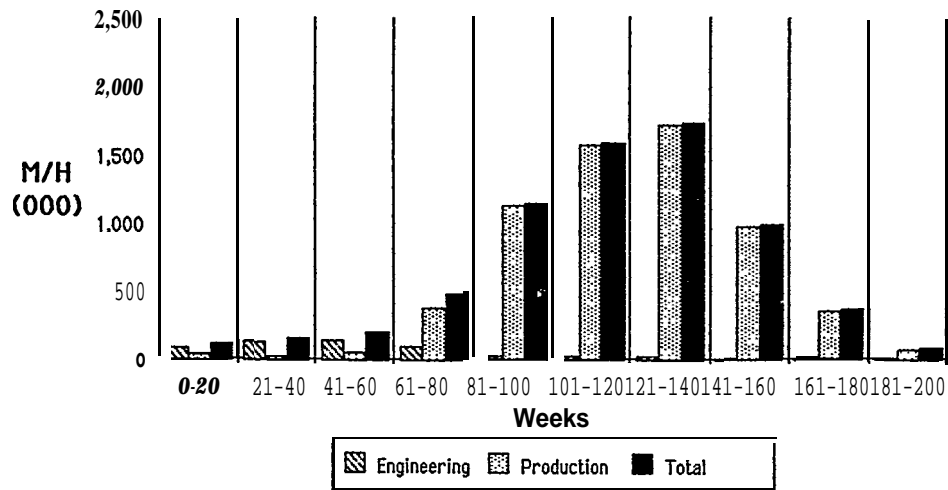


FIGURE 15: HISTOGRAM EXPENDITURE OF MANHOURS AT AVONDALE SHIPYARD

Communist Party, which also maintains the political organization that exists in the shipyard. The impact of the party and the state control is pervasive and strongly influences all decisions that are made by management. Since the beginning of the "Reform" (about 1980), however, management has slowly expanded its ability to make decisions on purely economic bases with less of a political orientation. The result has been more rational economic operations and a steady improvement in productivity.

The yard has not implemented a rationalized group technology production system, even though many of the characteristics associated with such a system are in place. The lack of a developed group technology is evidenced in the wide range of sizes of blocks that are processed in each of the production lanes. The same spread in block size is also evident in the total system the smallest block is nearly 50 times smaller than the largest block. (At Avondale this difference is a multiple of only 11:1).

The material lead time at Hudong, while better than that found in an American yard where only American-built material is permitted\*, is nonetheless burdensome. The Chinese yard can only order material from domestic sources twice a year; obtaining supplies or material from an overseas source requires approval of CSSC headquarters. This process adds about three months to the lead time requirements.

Hudong estimates that it will require 2.02 million manhours to build each of five steam turbine powered PD214 General Mobilization Ships. This is about 147 percent more manhours than was estimated in 1983 for Avondale, and about 340 percent more than was estimated by Kawasaki-Kobe in its 1980 study, [14] The only area where the American yard requires more manhours than Hudong is for engineering activities. But this difference is explained by the fact that Avondale has incorporated group technology and zone outfitting into its production system; such an approach requires significantly more man-hours, especially in the early years of implementation. Before adoption of group technology and zone outfitting, Avondale's engineering manhours were in the same approximate range as was that estimated

by Hudong for the PD214 ship.

Much of the difference in the productivity can be explained by the effect on Hudong of the political and social system in which the yard must operate. The Chinese manager cannot adjust his labor force at will; he must provide continuing employment and many of the social services to all of the workers assigned to his organization. In the case of Hudong, this is 12,000 people and their families. This fact colors every decision made by management. Manpower is approached as if it is a constant fixed cost. An improvement in productivity for a Process may not, in fact, reduce the yard's cost since the worker must still be paid. (There is, however, some change beginning to occur in this situation, and indications are that the manager will have greater control over work forces in the future.)

In the final analysis productivity is not the issue in a Chinese shipyard. The country is already one of the world's low-cost producers. The man-day rates (defined as direct costs and apportioned indirect costs) in the U. S. and Japan are at least 10 times that of China, and the differences in productivity are much less than that ratio. The issue is the purchaser's perception of quality. The ships put into the export market by China are still not perceived to be at a standard of quality that exists in Japan, South Korea, Taiwan, Western Europe, and the United States. The Chinese shipbuilders are aware of this difference, and are striving to change this image. Only time will tell the extent of their success.

#### ACKNOWLEDGEMENTS

The author is grateful to the Hudong Shipyard for its willingness to cooperate in the project, and for its continuing openness in responding to questions during the research effort. Without such cooperation the effort would have been impossible to accomplish.

Special thanks are also extended to the U. S. Maritime Administration for furnishing sets of the drawings and specifications of the PD214 ship, and permitting their use by Hudong Shipyard and by the study team.

In addition to the author, the study team was comprised of Hu Mao-Zi, Zhu Jun, Dow Pei-Lin, Hua Wei-Ha (translator), and twelve graduate and undergraduate students at Zhenjiang Shipbuilding institute. The material presented in this

---

\*At the time of the Avondale study, commercial ships built in U.S. yards for American-flag registrations were required to be built of American-made material. This is no longer the case, and Avondale today would have the option of purchasing equipment from abroad.

paper was based on data and analysis performed by the study team, which worked together on the project for the better part of a year. The dedication and cooperative spirit of the members of the team was an inspiration to the author, and the individual and group efforts are acknowledged with appreciation.

Lastly, and most importantly, gratitude is extended to the two universities that financially supported the project Zhenjiang Shipbuilding Institute in The People's Republic of China, and the University of Michigan in the United States. Both schools committed significant resources to the program. Zhenjiang's commitment was in permitting a large number of staff and students to work on the project, and covering associated out-of-pocket expenses of travel and per-diem costs. The University of Michigan's support was provided by the Transportation Research Institute and the Department of Naval Architecture and Marine Engineering, and included travel expenses to and from China for the author, and his salary during the period of involvement.

#### REFERENCES

- [1] *Maritime China* Summer, 1986, page 97.
- [2] *Ibid.*
- [3] *Ibid.*
- [4] *Construction Planning & Manpower Schedules for Single Screw Multi-Purpose Mobilization Ship PD214* Kawasaki Heavy Industries, U.S. Dept. of Commerce, MARAD, 1980
- [5] Bunch, H. M., *Comparison of the Construction Planning & Manpower Schedules for Building the PD214 General Mobilization Ship in a U.S. Shipyard and a Japanese Shipyard.*, U.S. Dept. of Commerce, MARAD, 1986.
- [6] *China Daily*, 1/12/87.
- [7] *PD214 Multipurpose Mobilization Ship* U.S. Dept. of Commerce, MARAD, November, 1978.
- [8] *Ibid.*
- [9] Bunch, op. cit.
- [10] *Business China*, January 5, 1983.
- [11] Bunch, op. cit.
- [12] *Manufacturing Technology for Shipbuilding--Project Condensation*, U.S. Dept. of Commerce, MARAD NSRP Report #0225, 1986.
- [13] *Manufacturing Technology for Shipbuilding Volume I, II, III, IV*, U.S. Dept. of Commerce, MARAD NSRP Report #137-140, 1982.
- [14] Bunch, H. M., *Comparison of the Construction Planning & Manpower Schedules for Building the PD214 General Mobilization Ship in a U.S. Shipyard and a Japanese Shipyard.*, *Journal of Ship Production* Volume 3, #1..

Additional copies of this report can be obtained from the  
National Shipbuilding Research and Documentation Center:

**<http://www.nsnet.com/docctr/>**

Documentation Center  
The University of Michigan  
Transportation Research Institute  
Marine Systems Division  
2901 Baxter Road  
Ann Arbor, MI 48109-2150

Phone: 734-763-2465  
Fax: 734-763-4862  
E-mail: [Doc.Center@umich.edu](mailto:Doc.Center@umich.edu)